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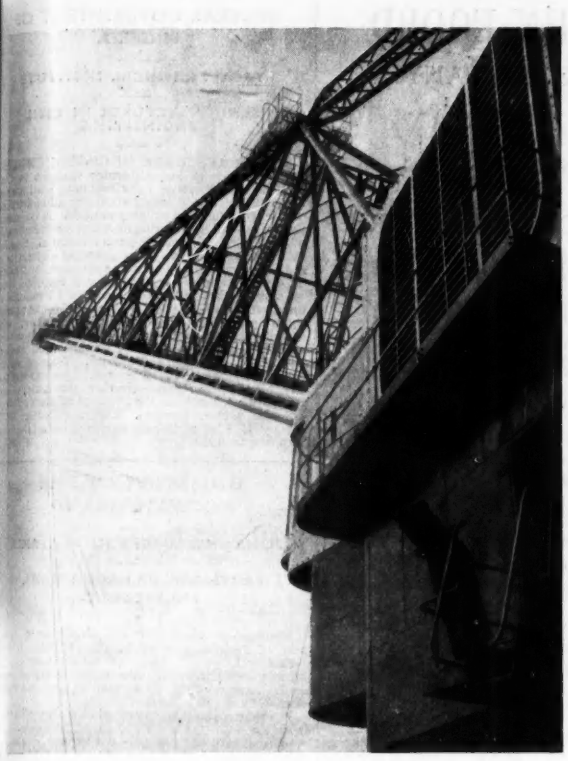

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"MECHANICALS" AT CAMBRIDGE

At first glance the city of Cambridge does not seem to offer very much of interest to mechanical engineers. Unlike Oxford, it has never become industrialised and there are only very few firms of engineering importance within its bounds. Of course, in King's College Chapel it has one of the world's finest Gothic buildings, the colleges are a delight to the eye, and no other city has anything comparable with the Backs. Engineers are certainly appreciative of such beauties. But one of the main purposes of the Summer Meetings of the Institution of Mechanical Engineers is to provide technical interest for those who participate. Fortunately, therefore, even though Cambridge itself has not very much to offer in that respect, it is a fine centre for reaching other places. Members of the Institution were able last week to visit Bedford, Luton, Dunstable, Letchworth, Chelmsford, Ipswich and Peterborough. Moreover, though there are few industries in Cambridge to provide technical interest, there is, instead, the engineering work of the University. How strange it is that of the two oldest universities in this country, that which is contained within the less industrialised city started much earlier than the other to teach technology. Only quite recently, by comparison, has the teaching of engineering been taken up at Oxford. The roots of that teaching at Cambridge go back certainly to 1837, when Willis was Jacksonian Professor of Natural Philosophy, and possibly even to 1796, when there were started lecture courses of a somewhat descriptive character covering engineering in all its branches. Many years had to pass, however, before engineering as such came to be recognised as a study satisfying in full the requirements for the award of a degree. The first step was the establishment of a Professorship of Mechanism and Applied Mechanics in 1875. Seventeen years later, when James Alfred Ewing held the professorship, there was established a Mechanical Sciences Tripos, that is, an honours course of study. Ewing laid down the general principles by which the course is still governed. It is designed to give students an understanding of the broad general principles which underlie all the main departments of engineering, structural, mechanical and electrical, rather than an intensive training in any one particular branch. There is, in fact, a strong tendency in an engineering course at Cambridge to stress the unity of engineering knowledge rather than its diversity. At the time of the Mechanical's meeting last week the undergraduates had gone down for the long vacation. That "spirit of eternal youth," to which the Mayor referred in welcoming the Institution to the city, was not in evidence. But so potent is the influence of the University over all the doings of those who live or stay for a few days at Cambridge that scarcely a speech was made at the meeting which did not make some reference to it.

Unquestionably the meeting was a success even though, as usual, it was attended only by a very small fraction of the total membership of the Institution. Certainly it served one of the purposes of a Summer Meeting, that of getting local members into closer touch with the affairs of their own Institution. But that purpose, after all, is somewhat introspective. The Institution should look outwards too. When far too many join it, solely to have the advantage of placing certain letters after their names, it is certainly right that the Institution should try to increase the proportion of members which take a real interest in its affairs. But it should surely also be the job of the Institution to introduce its members to people they would not in the ordinary course of their lives expect to meet. In particular it should, we think, take its members more frequently abroad to see what mechanical engineers in other lands are doing and to become acquainted with them. The exchange of knowledge about the science of engineering across the national boundaries in Europe is already pretty well organised. The Institution itself plays its part in spreading this information. But knowledge of engineering practice and means and methods of production is much less widespread, since it is only by going abroad to see what engineers are doing in other countries that a real impact can be made upon the mind. Moreover, except perhaps in the field of research, knowledge about personalities is lacking. Engineers in this country know personally or by repute all the more notable British figures working in their own specialist fields. But they are often quite ignorant of personalities abroad. In our view the

Institution should regard it as part of its job to break down this barrier by regularly taking its members abroad and thereby putting them into touch with engineers in other lands. The current discussions about the setting up of a Free Trade Area and the high probability that a Common Market will be set up within Europe make it all the more desirable that members of the Institution should be taken abroad. For without knowledge, for example, of the energy with which the Germans have set about the rebuilding of war-shattered cities and engineering works, without knowledge of their research and production methods, it is not possible to assess accurately what will be the effect if, over the major part of Europe, tariffs are eliminated and every firm within the area competes on equal terms with others in the same field. We recognise, of course, that we are really advocating a change in the traditional policy of the Institution. Only seldom in the past has it taken its members abroad, and each such visit has been considered a rather special occasion, whereas we are suggesting that visits abroad should become habitual. We recognise too that traditionally it has been left very largely to the incoming President to choose the town or city which shall next be visited by the Institution, whereas if meetings are to be held abroad the Council as a whole should make the choice, and an influencing factor may be the wish of some foreign engineering organisation, through whose kind offices an official invitation would be issued, that a particular centre should be chosen. But under the impact of changing conditions it is desirable not that traditions should be given up, but that they should be modified. Many members of the Institution, we believe, would like to see it become customary for an incoming President to choose, as a Summer Meeting place, not a centre in this country associated with his own work, but some centre on the Continent associated with the work of his competitors.

MIDGET SUBMARINES

The Admiralty did well to provide facilities for parties of schoolboys to look over the midget submarine H.M.S. "Sprat" during her recent stay in the Thames. It is a visit which they will remember all their lives. Although this little submarine is a modern vessel, launched just over two years ago, she differs little from her predecessors "X6" and "X7," which, against all the odds, carried out that brilliantly successful attack in 1943 on the "Tirpitz," hidden away miles up a Norwegian fjord, behind minefields, nets and defences of every description. Apart from small size, the essential difference between the midget and the normal submarine is that the former is equipped with an emergence chamber from which a "frogman"—a diver equipped with a self-contained breathing apparatus—can leave and re-enter the submarine at will, to cut nets or cables or to fix explosive charges on to the hull of an enemy ship. "X6" and "X7," in their attack on the "Tirpitz" did not, in fact, require to employ a diver either to cut the protective nets or to fix explosive charges. They carried two explosive charges in containers, one on each side of the submarine, which they released when in a position directly under the ship. It is, however, interesting to note that the requirements of war have over the years necessitated not only an increase of size of the normal submarine from the 63ft American-designed Holland boat of 1901 to the 281ft British submarine of the present day, but also the adoption of another kind of submarine—designed by another American, Mr. Lake—which at the beginning of the century found no favour as a fighting ship.

In Mr. Lake's view—fifty years ago—an underwater vessel was best employed on the sea bottom, while a diver left his emergence chamber to fix explosive charges, cut cables, destroy mines, &c.—very much indeed what a midget submarine is required to do to-day. To assist matters, he fitted the submarine with large wheels so that she could run along the bottom of the sea. Neither the shallow water diving equipment nor the emergence chamber bore much resemblance to their efficient counterparts seen in the modern midget submarine. But the idea was the same. The modern emergence chamber, which is flooded until the pressure is equalised, thus allowing the outer hatch to be opened and the diver to emerge, is completely reliable. Equally, the present-day, self-contained breathing apparatus enables a diver to work for a considerable time at depths down to 90ft. None the less, Mr. Lake's devices did work and it is probable his vessel was turned down by the British and United States navies because there seemed little use for her rather than because it appeared impractical. Moreover, by that time scientists and engineers had already overcome the age-long difficulties of designing an underwater vessel that seemed worthwhile. Her proper function, after submerging, it was felt, was to approach an enemy ship and fire a missile at her from a safe distance. These requirements were met by the use of an internal combustion engine for surface propulsion, and of storage batteries to provide electric propulsion when submerged. A reliable missile—the torpedo—which could be fired when submerged, already had, at that time, a range of several thousand yards. These new developments were all embodied in Mr. Holland's boat, which was accepted, after a good deal of hesitation by the Admiralty—a hesitation that was, indeed, natural. For 100 years successive Boards of the Admiralty had been consistent supporters of Admiral Lord St. Vincent's view that the development of underwater vessels could do nothing but harm to British seapower.

What, then, of the future? Britain is continuing to build both the normal and midget submarine. Four midgets have already been built since the war for the Royal Navy. It seems, therefore, that the Admiralty is not strongly impressed by the view held by the Defence Minister that a war fought with thermo-nuclear weapons would all be over in a very short time. The fact that the U.S.S.R. Navy is likely to have 700 submarines by 1960 suggests that Russian admirals are also unimpressed. It will not be easy for a submarine to escape detection and destruction if she deliberately comes within range of detection devices by making a close range attack. But in view of the three lines of radar defences across the American continent the Soviets may well regard the launching of guided flying bombs with thermo-nuclear warheads from submarines as a more effective means of delivering these missiles than from long-range bombers. Certainly it is safer at present to assume that navies, including submarines, will have their full part to play in a major war. In which case there will certainly be a need for the midget submarine—for a type of vessel which, aided by its small size, can penetrate nets and other defences guarding an enemy harbour. For not only could it sink a valuable ship, but it could also render the whole anchorage completely untenable by releasing containers filled with thermo-nuclear explosive!

The Engineer
100 Years Ago
(JULY 17, 1857)

"THE SUEZ CANAL"

"Lord Palmerston last week did not hesitate to give a very decided opinion as to the Suez Canal question; and if an opinion of his lordship is sufficient to prevent the carrying out of this scheme, it is, of course, shelved for this century at all events. We are not disposed to quarrel with the Premier as to his views, politically speaking—they may be sound or not, and it is not our province to discuss them—but when he asserts that the construction is *impracticable*, we take leave to say he is wrong. The *practicability* of the construction of the Suez Canal has been attested by the first engineers of the age, whose opinions none can venture to controvert. This is all we can say at present, and all we have ever said, so far; we leave other considerations for those better able than ourselves to settle, though we may venture to suggest, that what is sauce for the goose is usually considered ditto for her helpmate; and that if there be any weight in the suggestion, that our Indian possessions might be readily opened to the encroachment of Russia or France by the Suez Canal, it undoubtedly would at the present time, were it constructed, contribute very greatly to the relief of the public mind by facilitating the arrival of our troops in our disturbed Indian empire."

A Seven Day Journal

Engineering Careers for Girls

LAST week-end a conference, organised by the Women's Engineering Society, to discuss "Careers for Girls in Engineering," was held at Coventry Training College. The papers presented dealt with several aspects of engineering training and with the opportunities open in various branches of the engineering industry.

One of the papers was entitled "The Possibilities for Women Graduates in Engineering." It was presented by Professor D. C. Johnson, of Leeds University, who recalled that the Minister of Education had pointed out quite recently that the ability to be an engineer was not confined to the male sex. The women pioneers, Professor Johnson added, had proved their ability by becoming engineers in a somewhat hostile male world, and there was every reason to suppose that large numbers of women could be successful as engineers. It should be possible to say to girls "the door is open" but, Professor Johnson remarked, it was not quite as easy as that. He had asked several firms for their views about admitting girls to their various departments, electrical, chemical and aeronautical. From those inquiries it appeared that although a limited number of firms were willing to accept women, there was still a certain prejudice, and a few firms were definitely hostile; moreover, more than 50 per cent of the firms approached had not replied at all!

But despite this response, Professor Johnson went on, he felt that the engineering profession was a very rewarding and satisfying one, and he hoped that girls would be encouraged to take it up as a career. One of the difficulties, however, about the number of applications from women for entrance to the universities was the number of places available. Most universities were ready to accept women students in engineering, although in some instances entry had to be restricted. The woman student had to have a very high standard of education and ability, and technology could not be regarded as a second choice to pure science. Women accepted into universities to study engineering, Professor Johnson remarked, had to be of the highest calibre.

High Altitude Research

THE Symposium on High Altitude and Satellite Rockets, organised jointly by the College of Aeronautics, the Royal Aeronautical Society and the British Interplanetary Society, opened yesterday at the College of Aeronautics, Cranfield, Bletchley, Bucks. The papers on the first day included "Some Propulsion Problems of High Altitude Rockets," by Professor A. D. Baxter, Head of the Department of Aircraft Propulsion at the College, and the paper by K. J. Bossart which is abstracted on page 90. To-day, Dr. W. F. Hilton speaks on "Re-Entry and Recovery," presenting a radically new solution entailing a vehicle of low drag at zero lift but a very high induced drag when lift is generated to draw it inside an orbit; when within the atmosphere, it will maintain an absolute vacuum on the "cold" side for the protection of the crew and payload.

To-morrow, Saturday, there will be an exhibition including working demonstrations by the Royal Society, rockets, including "Skylark" models prepared by the Interplanetary Society, a rocket-firing demonstration and film shows. This exhibition, from 11 a.m. to 5.30 p.m., will be open to the public without registration.

Cavendish Bridge, Derbyshire

THE Cavendish Bridge, which carries the London - Carlisle - Glasgow - Inverness trunk road (A.6) over the River Trent near Shardlow, in Derbyshire, was opened to road traffic last Monday. The Ministry of Transport and Civil Aviation informs us that the contractor overcame a three months' setback caused by a heavy beam, forming part of one of the spans, falling into the river last October. The old bridge, built in 1758, was destroyed by floods in 1947 and was replaced by a Bailey bridge as a temporary measure; heavily laden vehicles then had had to make a 12-mile detour via Nottingham.

The Cavendish Bridge, which joins Derbyshire and Leicestershire, consists of three spans totalling 300ft and has been constructed in prestressed concrete by the Cementation Company, Ltd. The design, by Mouchel and Partners, Ltd., received the approval of the Royal Fine Art Commission. Its cost was £230,000. Long bridge embankments with culverts to provide outlets for flood water have been designed by the county surveyor of Leicestershire, Mr. R. R. W. Grigson, M.I.C.E.

Navigation Congress Dinner

THE nineteenth international congress of the Permanent International Association of Navigation Congresses was in progress in London last week and during the early part of this week; we conclude a brief account of the proceedings of the conference, which involved the presentation of about a hundred papers, on another page in this issue. A dinner was held at Grosvenor House on Monday, July 15 to commemorate the congress, and in the speeches which followed it praise was lavished upon the work of the various organising committees, and it was maintained that the congress had been highly successful.

The principal speaker was the First Lord of the Admiralty, the Earl of Selkirk, who proposed a toast to "The Association" and remarked on the value of an international meeting such as the congress, where agreement could be reached. He pointed out that on the last occasion when the Association had had a congress in London—in 1923—that toast had been proposed by the late Mr. Neville Chamberlain, who had stressed the growing interdependence of nations, and the importance of the work of engineers; these sentiments were equally true to-day, in the First Lord's view. He continued by emphasising the value of the freedom of the seas, and its importance to the standard of living maintained by all the nations represented at the conference, since heavy freight would always be carried by sea.

The First Lord's toast was followed by a response from Monsieur Gustave Willems, of Belgium, who is president of the Association. Then Viscount Waverley, the president of the congress, proposed the health of the guests, amongst whom he included all the overseas delegates present at the dinner. Mr. A. G. Maris, director general of the Rijk Water Staat of the Netherlands, replied on their behalf.

Royal Ordnance Factories

ON Monday last, the Minister of Supply, Mr. Aubrey Jones, answered questions in the House of Commons concerning the future of Royal Ordnance Factories, particularly that at Bishopton, Renfrewshire. He said that the fuse factory at Maltby and the filling factories at Swynnerton and Thorp Arch would close over the next several months, and dismantling of the T.N.T. factory at Irvine would begin immediately. Dalmuir would cease tank production in 1958, and the shell factory at Wigan and the small arms factory at Poole would close in 1959–60. These factories would be available for disposal to industrial concerns: those that remained would be regarded as preferred sources for the munitions they were equipped to produce, and their equipment would be kept up to date. Civilian work would be accepted to assist the factories to remain in being.

In response to supplementary questions, the Minister said that this implied that Bishopton would remain in being. He expected that the steps he had announced would reduce the expenditure of the country, and the number of workers employed, upon armaments.

Dr. R. W. L. Gawn

NAVAL architects in this country and indeed throughout the world will have learned with regret of the death of Dr. Richard William Lewis Gawn which occurred on Wednesday, July 10, at his home at Alverstoke, Gosport, Hampshire. Dr. Gawn, who was in his sixty-fourth year, had been superintendent of the Admiralty Experimental works at Haslar since 1938; he was a specialist in hydro-dynamic phenomena and carried out much work on propellers and cavitation problems. His work is well known abroad and he has played a large part in the International Towing Tank Conferences, having attended the first conference in Berlin in 1937. He was chairman of the Cavitation Committee and also of the Hydrofoil Research Working Party, and in addition Dr. Gawn served on committees of the British Shipbuilding Research Association, of the National Physical Laboratory, and of the Department of Scientific and Industrial Research. In 1908 he became a shipwright apprentice in Portsmouth dockyard and spent three years at the Royal Naval College, Greenwich, before being appointed to the Royal Corps of Naval Constructors in 1916. Three years later he joined the staff at Haslar for a short time and then, after service at the Admiralty, returned in 1934 as senior assistant to continue his work on research. Dr. Gawn presented a number of papers to the Institution of Naval Architects, of which he was a vice-president, and this year was awarded the William Froude Gold Medal in recognition of his work. The North East Coast Institution of Engineers and Shipbuilders awarded him the M. C. James Gold Medal and also its own Gold Medal for papers read before that body, and in 1953 the University of Durham admitted him to the degree of Doctor of Science in recognition of his work. His work was also honoured by his being awarded the O.B.E. in 1947 and being appointed a Commander of the Order eight years later.

Minor Losses in Metering Nozzles

By T. H. REDDING, M.Sc., F.Inst.P., A.M.I.Mech.E.*

(No. III—*Continued from page 44, July 12*)

An extended one-dimensional study of converging flow in closed channels leads to a general equation for the pressure drop versus (bulk) flow-rate relationship. This is sufficiently comprehensive to indicate the trends of variation of the value of the flow coefficient with respect to many possible variations in the flow conditions (both upstream of and within the convergence itself) which are not ordinarily taken into account in more elementary treatments of the subject. Following a comparative study of the geometry and flow-characteristics of two series of parallel-throated nozzles used for metering (A.S.M.E. and I.S.O. metering nozzles) the above equation is used to evaluate and discuss probable values for the minor energy-loss factors (or so-called "minor losses"), which define the extent to which irreversible work is done by the fluid in the course of its passage through the nozzle. These evaluations reveal systematic but opposite tendencies in the manner in which the respective (A.S.M.E. and I.S.O.) minor losses vary with the throttle (area) reduction-ratio, and are shown to be such as to substantiate known (or probable) characteristic features of the flow patterns, as have been determined (or inferred) from other experimental and theoretical studies in this field.

Energy Loss Factor

I.S.O. Nozzles.—Values of E for I.S.O. nozzles, calculated in the same manner as for the A.S.M.E. nozzle, are shown in Fig. 12, the relevant flow coefficient data having been derived from that given in the sixth edition of *D.I.N.*, 1952,[8] and the pressure gradient data given in the aforementioned paper by Witte.[12] Fig. 12 is plotted for sensibly the same values of the area-reduction ratio as for the A.S.M.E. nozzles.

The formula used to convert the flow coefficient relevant to corner taps $(\alpha)_c$ to those relating to 1D-nozzle exit taps (α_e) follows on eliminating G from the general flow equation as written with respect to each of these two positions of the pressure taps. The relevant conversion formula is $\alpha_e = \alpha_c/\sqrt{1+q_{2e}-q_{1e}}$, with $q_{1e}=(\delta P)_{1e}/(\delta P)_c$ and $q_{2e}=(\delta P)_{2e}/(\delta P)_c$; where $(\delta P)_{1e}$, $(\delta P)_{2e}$ and $(\delta P)_c$ are the pressure differences between the upstream corner tap and a tap distant 1D-upstream of the nozzle-entrance section, the downstream corner tap and the "nozzle-exit" (downstream) pipe-wall tap, and between the upstream and downstream corner taps respectively—see Fig. 12 (inset *a*). As mentioned previously, the pressure gradient data used in these calculations refers to a pressure tapping-hole diameter $\delta=0{\cdot}01D$.

Although, with this value of the tapping-hole diameter, Witte's experiments on the pressure gradient are confined to an 8in diameter main, these results have been applied to a 4in diameter main in order to effect a comparison with the A.S.M.E. nozzle form. This is considered justifiable in view of Witte having established the pressure gradient data as being independent of the pipe diameter (over the range 2in to 8in), even though the tapping-hole diameter used in these latter experiments is $\delta=0{\cdot}03D$.

Although the values of the energy loss factor, as determined by the above calculations, are necessarily approximate, they are probably sufficiently accurate to establish the general trend of variation of E with respect to m and R_d ; this is apparent from the detailed examination—given in Appendix II—of the basic data and assumptions on which the calculations are based.

Thus, it would appear that two features of the characteristics shown in Figs. 11 and 12 call for special attention, viz. that at a given Reynolds number, E increases with increasing m in the case of the A.S.M.E. nozzle, but decreases with increasing m in the case of the I.S.O. nozzle. In view of the observations made in Appendix II, we shall attach no significance to the fact that, for some values of m, $E_{I.S.O.}>E_{A.S.M.E.}$; but note that in spite of the uncertainty of basic data, theoretical values of $E_{I.S.O.}$ are such as to be comparable with those of $E_{A.S.M.E.}$ On the other hand, for the purpose of the discussion which follows, we shall accept, as established, the tendency of $E_{I.S.O.}$ to decrease with increasing values of m. If the above evaluations of E are substantially correct, or, for that matter are no more than truly indicative of the general trend of variation of E with respect to m and R_d, it seems reasonable to attribute their characteristically opposite tendencies as being indicative of peculiarities in the respective flow patterns of the two devices. It is, therefore, of some interest to determine to what extent it is possible to attach physical significance to the results and so, perhaps, predict some of the more pertinent features of the flow pattern as a whole. For this purpose we shall seek to determine the manner in which the total energy loss Z is divided between the cylindrical exit piece (or throat) and the "complete approach path," this being defined as the flow path between a section 1D upstream of the nozzle-entrance section (section A_{1M}) and the entrance section of the cylindrical exit-piece itself A_{20} (see definition sketch of Fig. 9 (*c*) *ante*).

Such a calculation is possible if, following Shapiro and Smith,[22]‖‖ we accept Langhaar's[23] integration of the Navier-Stokes equation relating to pipe inlet flow as applied to the cylindrical exit piece (which follows the curved entrance) of metering nozzles, since this study leads to an expression for both the velocity profile at any distance (x say) from the throat inlet and the corresponding pressure drop at any given value of the Reynolds number. To be sure, this integration does require upstream conditions such as will ensure a uniform velocity distribution over the throat entrance section ; but we will assume that the curved entrances of metering nozzles are effective in satisfying this requirement (cf., Nikuradse experiments on rounded inlets reported in reference 21).

Thus, conventionally, we write the expression for the pressure drop in the exit piece as

$$P_{20}-P_{2e}=4\bar{f}_A\frac{l}{d}\gamma\frac{v_2^2}{2} \quad . \quad . \quad . \quad (32)$$

where v_2 is the (geometrical) bulk velocity $(\equiv Q/\pi d^2)$ in the exit piece, P_{20} and P_{2e} are the wall pressures at the entrance and exit sections (A_{20} and A_{2e}) respectively of the nozzle exit piece, l the length, and $\bar{f}_A$ the so-called, integrated apparent friction coefficient¶¶ of the exit piece.

According to Langhaar, $\bar{f}_A$ can be computed as a function of R_d and l/d—always providing that over the length l/d the boundary layer retains a laminar character. Reference to the experimental work of Shapiro and Smith[22] shows this to be the case providing $R_d.l/d<200{,}000$ (i.e. $R_d<333{,}333$ when $l/d=0{\cdot}6$, and $R_d<666{,}666$ when $l/d=0{\cdot}3$). These values refer to an area reduction ratio of $m=0{\cdot}022$ and with a uniform velocity distribution (produced artificially) in the approach channel. In practice, therefore, the boundary layer will probably have gone turbulent at some point in the exit piece even for Reynolds numbers less than values quoted above ; thus, the acceptance of Langhaar's value for $\bar{f}_A$ will, in the present problem, probably result in a general under-estimation of the factor $\bar{f}_A$.

For reference purposes Langhaar's evaluation of $\bar{f}_A$ is reproduced in Fig. 14, the which values (or extrapolations thereof) are used in the computations which follow.

We now identify reference stream surfaces S_{10} and S_{20} whose peripheries lie within the nozzle-entrance section A_{10} and the exit-piece entrance section A_{20} respectively—noting that, if no separation occurs, the peripheries of these stream surfaces coincide with those of the relevant nozzle sections (see Fig. 9(*c*)).

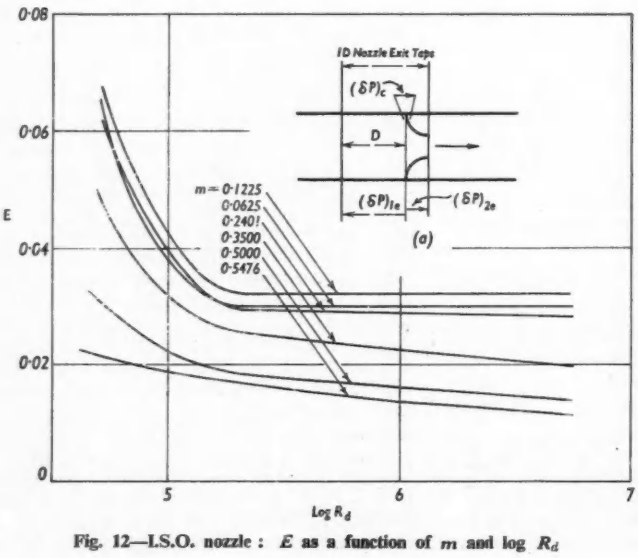


Fig. 12—I.S.O. nozzle : E as a function of m and log R_d

* British Scientific Instrument Research Association.

‖‖ Shapiro and Smith utilised Langhaar's expression for the energy loss in pipe inlet flow to predict the coefficient of discharge of a (low ratio) A.S.M.E. nozzle at low values of the Reynolds number and zero velocity of approach.

¶¶ In fact, $\bar{f}_A=\dfrac{\int_0^{l/D} f_A d(x/d)}{l/d}$, where f_A is the local apparent friction coefficient, as defined by the equation $dP=4f_A\dfrac{dx}{d}\cdot\gamma\dfrac{v^2}{2}$, in which v is the (geometrical) mean velocity $(Q/\pi d^2)$ at distance x from pipe entrance.

Here it is important to notice that dP (and thus f_A and $\bar{f}_A$) is a function of both the frictional energy losses and the change which takes place in the velocity profile over the elemental length dx. Further, in such regions of developing velocity profile, $f_A>f$—the true local drag coefficient, as defined by the local shear intensity at the nozzle wall.

Again, we identify P_{10} and P_{20} as the wall pressures at the peripheries of pipe sections A_{10} and A_{20} respectively, and use the symbols θ_{10}, θ_{20}, μ_{10}, μ_{20}, C_{10}, C_{20}, with respect to the relevant stream and nozzle sections, with the same meaning as heretofore. Furthermore, let Z_1, Z_2 and Z_3 represent the work done by friction per unit mass of fluid during its passage from S_{1M} to S_{10}, S_{10} to S_{20} and S_{20} to S_{2e} respectively, and E_1, E_2 and E_3 the corresponding energy loss factors defined with respect to the bulk exit-piece velocity v_2, so that

$$Z_1=E_1\frac{v_2^2}{2} \quad . \quad . \quad . \quad . \quad (33.1)$$

$$Z_2=E_2\frac{v_2^2}{2} \quad . \quad . \quad . \quad . \quad (33.2)$$

$$Z_3=E_3\frac{v_2^2}{2} \quad . \quad . \quad . \quad . \quad (33.3)$$

with the obvious relations

$$Z=Z_1+Z_2+Z_3 \quad . \quad . \quad . \quad . \quad (34)$$

$$E=E_1+E_2+E_3 \quad . \quad . \quad . \quad . \quad (35)$$

where Z, as previously, is the total work done by friction per unit mass of fluid in its passage between sections A_{1M} and A_{2e} (i.e. "1D nozzle exit tapping positions") and E the corresponding energy loss factor.

If now P_{1M} is wall pressure at $1D_1$ the upstream pressure tapping (at section A_{1M}), α_e and α' the flow coefficients relating to pressure tappings taken between sections A_{1M}, A_{2e} and A_{1M}, A_{20} respectively, we have (by definition),

$$G=\alpha_e A_{2e}\sqrt{2\gamma(P_{1M}-P_{2e})} \quad . \quad . \quad (36)$$

$$G=\alpha' A_{20}\sqrt{2\gamma(P_{1M}-P_{20})} \quad . \quad . \quad (37)$$

Numerically, $A_{2e}=A_{20}$, so that G can be eliminated between (36) and (37) to give

$$\frac{(\alpha_e)^2}{(\alpha')^2}=\frac{P_{1M}-P_{20}}{P_{1M}-P_{2e}} \quad . \quad . \quad . \quad (38)$$

However, since

$$P_{1M}-P_{2e}=(P_{1M}-P_{20})+(P_{20}-P_{2e}) \quad . \quad (39)$$

$$1=\frac{P_{1M}-P_{20}}{P_{1M}-P_{2e}}+\frac{P_{20}-P_{2e}}{P_{1M}-P_{2e}} \quad . \quad . \quad (40)$$

Also, since

$$v_2=\frac{G}{A_{2e}\gamma} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (41)$$

we can write (32) as

$$P_{20}-P_{2e}=2\bar{f}_A\frac{l}{d}\frac{1}{\gamma}\left(\frac{G}{A_{2e}}\right)^2 \quad . \quad . \quad (42)$$

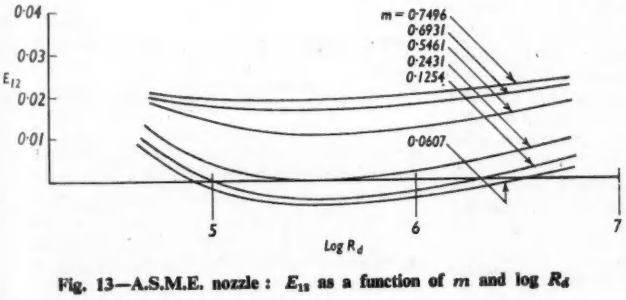
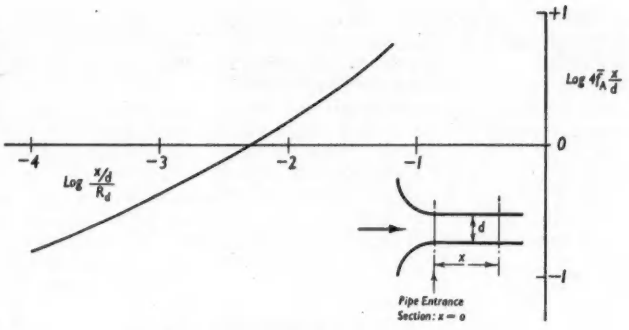


Fig. 13—A.S.M.E. nozzle: E_{12} as a function of m and log R_d



$\bar{f}_A$ = integrated apparent friction coefficient between inlet section of pipe (of diameter d) and section distant x from inlet section.
R_d = Reynolds number of flow in pipe.
Log $4f_A\cdot\frac{x}{d}$ versus log $\frac{x/d}{R_d}$, after Langhaar (see reference 23

Fig. 14—Laminar flow in pipe-inlet: characteristic log $4\bar{f}_A\cdot\frac{x}{d}$ versus log $\frac{x/d}{R_d}$

so that $\frac{1}{\gamma}\left(\frac{G}{A_{2e}}\right)^2$ can be eliminated between (36) and (42) to give

$$\frac{P_{20}-P_{2e}}{P_{1M}-P_{2e}}=4\bar{f}_A\frac{l}{d}\alpha_e^2 \quad . \quad . \quad . \quad . \quad (43)$$

A relation between α_e and α' now follows immediately on eliminating $\frac{P_{1M}-P_{20}}{P_{1M}-P_{2e}}$ and $\frac{P_{20}-P_{2e}}{P_{1M}-P_{2e}}$ between equations (38), (40) and (43) to give

$$\frac{(\alpha_e)^2}{(\alpha')^2}=1-4\bar{f}_A\frac{l}{d}\alpha_e^2 \quad . \quad . \quad (44)$$

If, now, Bernouilli's equation is applied to the "complete approach path"—i.e. to the flow path between reference sections A_{1M} and A_{20}—we can use similar arguments as before (for case of flow path between reference sections A_{1M} and A_{2e}) to derive an analytical expression for α', viz.

$$\alpha'=\frac{1}{\sqrt{C_{20}-C_{1M}m^2+(E_1+E_2)}} \quad . \quad . \quad (45)$$

Again, as before, we assume $C_{20}=C_{2e}=1$, and eliminate α' between (44) and (45) to obtain the required expression for E_1+E_2 (E_{12}, say), the energy loss factor in the complete approach path, viz.

$$E_{12}=E_1+E_2=\frac{2(Z_1+Z_2)}{v_2^2}$$

$$=\frac{1}{\alpha_e^2}-4\bar{f}_A\frac{l}{d}-(1-C_{1M}m^2) \quad . \quad (46)$$

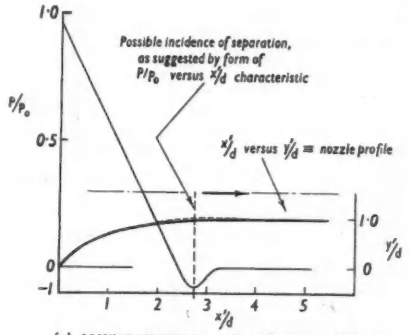
Fig. 13 shows a plot of E_{12} versus R_d at selected (constant) values of m for the case of the A.S.M.E. nozzle, from which it appears that, at constant Reynolds number, E_{12} increases with increasing m. At values of m below $m=0\cdot24$ (approximately), E_{12} sometimes assumes impossible (i.e. negative) values—a fact which emphasises the essential incorrectness of some of the assumptions on which the calculations to determine E_{12} are made. However, the treatment, as a whole, is probably satisfactory in so far as it indicates (*a*) increasing values of the energy loss factor E, with increasing m at constant R_d, and (*b*) that the true nature of the flow is otherwise than that appertaining to the simple inlet system taken as a basis in deriving the formula for E_{12}—this to a degree that theoretical values of E_{12} appear as negative quantities for certain values of m. Conclusion (*b*), it might be noticed, is in no way altered if we assume that the acceptance of Langhaar's value of $\bar{f}_A$ has resulted in an underestimation of $4\bar{f}_A\cdot l/d$.

A similar analysis for the case of I.S.O. nozzles shows E_{12} either as a negative quantity, or small positive term, according to the value of R_d and m. However, in view of the much less satisfactory data used to evaluate α_e, it would be imprudent to draw conclusions from these results other than the aforementioned reference to the total energy loss factor, which at a given value of R_d appears to decrease with increasing values of m.

Anticipation of Separation Phenomena

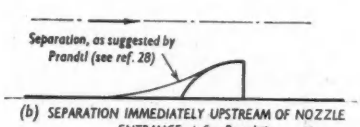
Conceivably, the characteristic qualities of the above curves can be explained in more than one way, but it is interesting to notice the correlation that exists between an explanation based on the assumption of separation phenomena and probably properties of the nozzles, as inferred from other theoretical and experimental studies in this subject.

Thus, in the case of A.S.M.E. nozzles, decreasing values of E with decreasing m (at constant R_d) could be attributed to decreasing eccentricity of the nozzle-entrance curve (cf. Fig. 8(*a*)), this being such as to cause local zones of separation or to increase the amount of such separation if, in fact, this is a characteristic feature of the flow pattern which occurs to some extent at all values of the reduction ratio m. The likelihood of this being the case, with separation taking place in the near vicinity of the pipe entrance (as shown in Fig. 15(*a*)) is evident from other



(*a*) POSSIBLE SEPARATION AT ENTRANCE TO THROAT.

P = wall pressure distance x' from nozzle entrance.
P_0 = wall pressure in throat.
P/P_0 versus x'/d, after Rouse and Hassan (see reference 24).

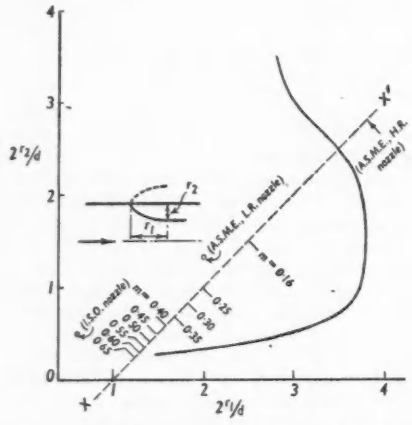


(*b*) SEPARATION IMMEDIATELY UPSTREAM OF NOZZLE ENTRANCE. (after Prandtl).

Fig. 15—Separation phenomena

studies in which elliptical nozzle forms have been involved. Thus we observe that the geometrical conditions specified by Rouse and Hassan[24] to ensure separation free flow through elliptical entrance pieces are not satisfied by A.S.M.E. metering nozzles, and, moreover, that the deviation from the ideal form tends to increase as the area-reduction ratio decreases to (approximately) $m=0\cdot25$, but becomes less apparent as the area ratio approaches its limiting value $m=0\cdot16$.

In Rouse and Hassan's*** investigation, the pattern appertaining to potential flow in an elliptical entrance piece is determined by an accurate rheo-electrical method. The experiments actually determine the conditions under which the local wall pressure in the entrance piece falls below that in the throat, it being assumed that separation, if apparent, is most likely to occur in locations where these conditions prevail. (If the local wall pressure falls below the vapour pressure of the fluid, cavitation—and subsequently separation—will almost certainly take place.) Thus, for a given value of r_2/d, limiting minimum values are determined for r_1/d, which must be exceeded in order to ensure separation-free flow through the entrance (see Fig. 16).



r_2 = length of transverse axis.
r_1 = minimum length of axis, parallel to direction of flow, consistent with wall-pressure in entrance curve being at all points greater than that in the throat.
$2r_1/d$ versus $2r_2/d$, after Rouse and Hassan (see reference 24).

Fig. 16—Elliptic nozzles: conditions for ensured separation-free flow

However, when these conditions are not satisfied the wall pressure does not fall continuously along the curved entrance piece, zones of depression—and thus of possible separation—occurring a short distance upstream of the point at which the entrance curve merges (tangentially) with the cylindrical exit piece. At this point—where the local (unseparated) drag coefficient is approaching its maximum value—the occurrence of separation could be expected to have an appreciable effect on the energy loss factor. Thus, if we assume negligible energy losses (due to eddies) in the (necessarily) thin layer of "dead water" adjacent to the pipe wall, it is conceivable that E will decrease according to the extent to which separation takes place. Reference to Fig. 16 (on which the proportions of A.S.M.E. and I.S.O. nozzles are represented by the broken line X–X) shows that A.S.M.E.—and I.S.O.—specified values for r_1/d relevant to given values of r_2/d, invariably fall short of the maximum value for (ensured) separation-free flow. Thus, in these circumstances, we may anticipate the occurrence of separation, and probable reduction in energy loss factor, according to the extent to which the proportions of the nozzle deviate from those necessary to ensure separation-free flow.

Again, in regions of lo[illegible]ds numbers, it has long been susp[illegible] separation occurs in the curved [illegible] pieces of metering nozzles, the [illegible]eing large enough to cause abrupt cha[illegible] in the flow coefficient. This was first noticed by Bean, Reynolds and Johnson,[1] who measured flow coefficients with respect to conventional tapping positions and later by Engel[27] whose measurements were made with the downstream pressure tapping in the position where separation probably occurs. With this latter arrangement the flow coefficient data is very susceptible to the degree of separation, since the constitutional formula for the flow coefficient must now include a "contraction" term to take into account the thickness of the layer of dead water into which the downstream pressure tapping connects.

In the case of the I.S.O. nozzle it is conceivable that the extent of the separation at the entrance to the throat is comparable with, or greater than, the largest separation occurring in the A.S.M.E. family of nozzle-entrance curves—since the I.S.O. entrance curve is further removed from Rouse and Hassan's ideal than even the least satisfactory of the A.S.M.E. family of entrance profiles (i.e. that relevant to m=0·16). On the other hand, the throat separation should be independent of m in so far as I.S.O. nozzles are concerned, in view of the eccentricity of the entrance curve being itself independent of m. If separation at the throat entrance is the only peculiarity of the system we would expect $E_{I.S.O.}$ to be independent of the reduction ratio m. The fact that this is not the case—seeing that E tends to decrease with increasing m—suggests the possibility of a further zone of separation, the effect of which, with respect to varying m, is opposite to the aforementioned separation in the throat. On this point it is of interest to observe that separation in the immediate upstream vicinity of a convergence has, in special cases, been established by direct observation, notably by L. Prandtl[28] and A. Betz.[29] According to these authorities, we might well expect (secondary) zones of separation immediately in front of the nozzle-entrance section, in the "corner" formed by the pipe wall and the nozzle-entrance section itself (see Fig. 15(*b*)). In this connection, we might note that the presence of such separations is suggested—but not confirmed—by the stationary value of the wall-pressure gradient in the very near upstream vicinity of the nozzle entrance (see Fig. 7). Moreover, it is equally conceivable that such separation occurs upstream of A.S.M.E. nozzles (in spite of their easier entrance curves and smaller dam heights), but that its effect on the flow coefficient—and, hence, on the characteristic "E versus m"—is masked by the m–dependent separation which takes place at the entrance to the throat.

Conclusion

The above discussion has served to establish quantitatively a correlation between computed values of the loss factor E—as determined by reference to one-dimensional theory—and certain characteristics of the flow pattern as known or inferred from the direct measurements, theoretical studies on the irrotational flow of inviscous fluids, and from the study of rheo-electrical analogues. Furthermore, it is probably impossible to carry out a more precise investigation or to reach more definite conclusions regarding the behaviour of the energy loss factor (or of other factors which occur in the constitutional formula for the flow coefficient), without first having recourse to the results of more precise determinations of the flow coefficient, the pressure gradient upstream and downstream of pipe nozzles, and to direct determinations of the kinetic energy correction factor C_1.

In the author's opinion, it is necessary, for this purpose, to determine α_p to an accuracy of the order $\pm^1/_{10}$ of 1 per cent—a requirement which makes formidable—but probably not impossible—demands on experimental techniques. It is not sufficient merely to measure bulk flow rate and pressure difference to this degree of accuracy: it is equally important to control, to the same order of precision, the flow conditions under which these measurements are made. With modern equipment, pressure differences are probably often measured with 0·10 per cent accuracy, even in commercial flow-metering practice. The fact that the probable error in the resultant flow-rate reading is of the order of $\pm$1 per cent is due, not only to unavoidable changes in the approach conditions, but also to so-called "normal" conditions being insufficiently well defined. Thus, in order to ensure reproducibility of the flow coefficient—as from one installation to another—to an accuracy of 1 part in 1000 would certainly require specifying conditions which would ensure the reproducibility (i.e. stabilisation) of the separation effects within the nozzle itself. In fact, with most commercial fluids (which often contain indeterminate amounts of dissolved gases) it may be impossible to do this without altering the proportions of the nozzle to be more in agreement with those appertaining to separation-free flow. However, increasing the length of the nozzle may be inadmissible, either from the point of view of economy, convenience of installation, or in view of the increase in permanent pressure drop that would result. In fact, with a given nozzle form, it may well be that separation phenomena within the curved entrance piece of the nozzle itself inherently set limits to the degree of accuracy with which flow measurements can be made, and that further investigations on the effect of entrance profile will result in new nozzle forms in which separation effects (even if more pronounced) will be inherently more stable than in the A.S.M.E. and I.S.O. nozzle forms discussed in this article.

Appendix I.—Derivation of the Relation between C and R_D

Consider the case of fully developed turbulent flow in a pipe of circular section, and let the velocity profile be represented by an equation of the form

$$\frac{w_1}{V}=f\left(\frac{r}{r_0}\right) \quad . \quad . \quad . \quad . \quad . \quad \text{(i)}$$

where w_1 is the local stream velocity at a distance r from the axis of the pipe, of assumed diameter $D=2r_0$.

Then, according to Bakhmeteff,[17]

$$f\left(\frac{r}{r_0}\right)=\frac{1}{k}\sqrt{\frac{\lambda}{8}}\left\{\left(k\sqrt{8/\lambda}+\frac{3}{2}\right)+\log\left(1-\frac{r}{r_0}\right)\right\} \quad . \quad . \quad . \quad . \quad . \quad \text{(ii)}$$

where k is a constant and λ the usual pipe resistance coefficient, as defined by the relation

$$\frac{dP}{dx}=\lambda\frac{1}{D}\gamma\frac{V^2}{2}.$$

We now effect the substitutions

$$w_1=Vf\left(\frac{r}{r_0}\right),\ G=V\pi r_0^2\gamma,\ dG=w_1\gamma 2\pi r dr$$

into equation (11.1) to express the kinetic energy correction factor in the form

$$C_1=2\int_0^1\left[f\left(\frac{r}{r_0}\right)\right]^3\frac{r}{r_0}d\left(\frac{r}{r_0}\right) \quad . \quad . \quad . \quad \text{(iii)}$$

*** The application of these results to real flow is tantamount to assuming the boundary layer being sufficiently thin to permit our assuming (normal) pressures over the pipe wall to be sensibly the same as those associated with the potential flow field. However, this assumption is probably valid at points in vicinity of the entrance to the throat where local separation is most likely to occur.

and notice that $f\left(\frac{r}{r_0}\right)$ can be eliminated between equations (ii) and (iii) to give C_1 as a function λ.

This relation is shown in Fig. 10, after the numerical evaluation due to Engel and Davis,[15] which determines C_1 as a function of λ over the range $\lambda=0$ to $\lambda=0{\cdot}06$. However, λ is a function of R_D, which for smooth pipes has been established as a result of the work of Nikuradse[18] and Blasius[19, 20]; in this case, therefore, C_1 is determined as a well-established function of the Reynolds number R_D.

Appendix II.—Evaluation of the Energy Loss Factor E: Validity of Basic Data

Further to the evaluation of E, it is of interest to review the basic data on which the calculations are made, in order to determine to what extent it is permissible to draw conclusions regarding the nature of the flow from the computed values of the energy loss factor.

A.S.M.E. Nozzles

In this case the basic discharge coefficient is probably correct to within $\pm 0{\cdot}2$ per cent, which, at a given value of R_d, amounts to a (maximum) error in the estimated value of E of only $\pm 0{\cdot}15\Delta E$, where ΔE is the total variation in E consequent on m varying over the range 0·06 to 0·74. Furthermore, the pressure gradient data used in the calculations is again the result of precise measurements and is unlikely to introduce any substantial error in the estimated values of E. Even at the lower Reynolds numbers (where the use of available pressure gradient data is perhaps open to criticism), the error in E due to inaccuracy in the measurement of dP/dx is probably small, since in converting α_p to α_e only downstream pressure gradient data is used, and this over the relatively short distance between the downstream pressure tapping and the extremity of the nozzle. [It is, however, interesting to observe the claim that pressure gradient data—as expressed in terms of $(\Delta P)_1/(\Delta P)_M$ and $(\Delta P)_2/(\Delta P)_M$ is independent of the rate of flow—see reference 5, page 241.]

Possible inaccuracy in the assessment of C_{1M} will introduce a regular error into the computed value of E, the order of magnitude of which amounts, at the most (i.e. when $m=0{\cdot}74$), to only $0{\cdot}06\Delta E$ per 5 per cent variation in the (assumed) value of C_{1M}. The corresponding variation in the calculated value of E (at $m=0{\cdot}74$) for a 5 per cent variation in the value of C_{2e} is approximately twice this amount, although in this case it is extremely unlikely that C_{2e} can be appreciably different from its assumed value of unity. (Experiments by Nikuradse[21] have shown this to be the case for the entrance section of a pipe when this is preceded by a bell-mouthed approach, whilst the theoretical considerations of Langhaar[23] justify the assumption that variations in C_2 can be neglected over the very short length of exit pieces used in the types of metering nozzles under consideration.)

Finally, an error must be introduced due to the assumption that the pipe-wall pressure at the (downstream) section, which contains the nozzle exit, is the same as in the nozzle exit itself. It is extremely difficult to assess the order of magnitude of this error, but on the basis of assuming a (downstream) pressure gradient across the pipe as being not greater than the mean pressure gradient along the wall, the maximum error in the computed value of α_e (occurring at $m=0{\cdot}25$) amounts to 0·18 per cent.

Taken as a whole, the above observations on data relating to α_p, C_{1M}, C_{2e} and the pressure gradients concerned, tend to substantiate the value of E (as computed from equation (31)), and certainly the general trend of the curves of Fig. 11.

I.S.O. Nozzles

A similar scrutiny of the assumptions made in computing values of E in the case of I.S.O. nozzles, is, however, far less satisfactory. In this case, lack of direct data on the flow coefficient relating to pipe-wall taps, necessitates α_e being calculated from a knowledge of α_c, together with upstream—as well as donwstream—pressure gradient data. Available data on this subject (expressed in terms of $(\delta P)_1/(\delta P)_c$, and $(\delta P)_2/(\delta P)_c$), relates to determinations by Witte,[12] who experimenting with both orifices and nozzles, determines $(\delta P)_1/(\delta P)_c$ and $(\delta P)_2/(\delta P)_c$ as being independent of R_d, even when α_c itself is sensitive to varying R_d; but this fact, at least in so far as orifices are concerned, is contrary to the findings of both Johansen[25] and Engel.[26] Moreover, as mentioned previously, further uncertainty is introduced into these calculations (to determine α_e) due to the pressure gradients—and more particularly the upstream pressure gradient—being dependent on the diameter of the pressure tapping hole δ.

The values of E derived for the I.S.O. nozzles are therefore increasingly liable to suspicion with decreasing Reynolds number. Consequently, except when $R_d > 500{,}000$ (when α_c is independent of R_d), it would be unwise to attribute physical significance to the computed value of E, and even in the range of high Reynolds numbers, conclusions regarding the value of E have to be based on much less certain data than in the case of the A.S.M.E. nozzle form.

Errata

The legends appearing in small type above the captions of Figs. 2, 3, 5, and 6 relate to Figs. 3, 4, 6, and 7 respectively. Page 41, column 2, line 4 should read "$R_d=\frac{V_d d}{\eta\gamma}$ where V_d is fluid velocity in throat"; and line 8 should read "[Thus $R_D=\sqrt{m}R_d$]". Page 43, column 1, line 10: for sentence beginning "From equation (25) . . . . . " read "From equation (25) it is apparent that G is only proportional to $\sqrt{P_1-P_2}$ when Y_1, and Y_2 or (Y_1-Y_2) are independent of P_1-P_2."

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Cast Iron Research

The British Cast Iron Research Association has recently held some open days, on which many hundreds of visitors were enabled to see the laboratories at Bordesley Hall, Alvechurch. The latest addition to the laboratories is a new melting shop which was formally opened, on July 3, by Mr. J. J. Sheehan, president of the Association. In the melting shop there are installed two oil-fired tilting crucible furnaces, each of 250 lb capacity, and an oil-fired lift-out crucible furnace of 80 lb capacity. There is also some high frequency melting equipment, consisting of four furnaces of 10 cwt, 5 cwt, 2 cwt and 1 cwt capacities, operated by a 200kW motor alternator. A 3 cubic foot capacity sand mill is loaded by an electrically operated skip hoist which is fed from a rotary screen and magnetic separator. The equipment of the melting shop is not yet complete, but provision has been made to add facilities for cupola melting, including hot-blast melting, in the near future.

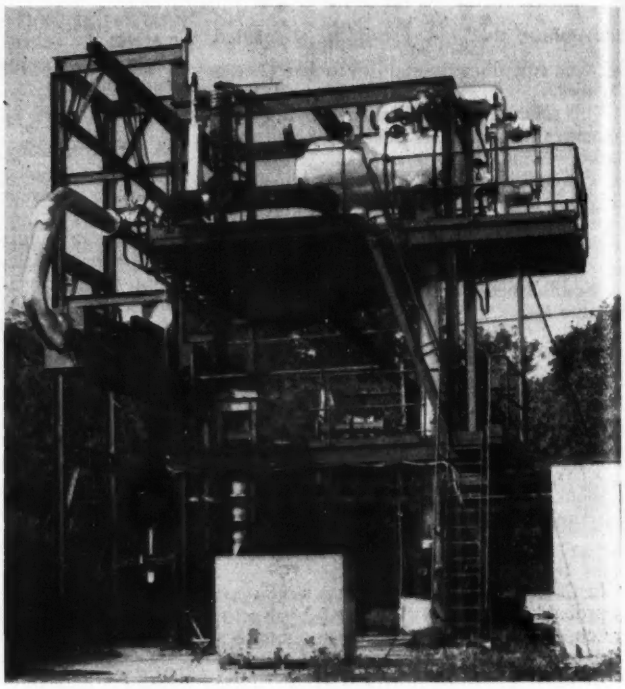
Future extensions planned by the council of the Association include a building for practical work on dust control and the working atmosphere of the foundry. The "foundry atmospheres section" was formed as a branch of the Association's development department in 1951, as there was, of course, increasing need for experimental work directed to the improvement of foundry conditions. The activities of the section comprise an advisory service and experimental work on dust flow and dust control. One of the first duties of the experimental team was to make surveys of dust concentrations at various points in mechanised, partly mechanised and non-mechanised foundries. From an analysis of these surveys it was significant that dust concentrations obtained during pouring were so high that it was difficult to relate and identify foundry equipment and processes that were the sources of dust production. Consequently, the team was directed to investigate some matters which were known to be responsible for passing dust-bearing air streams into the breathing zone (such as the pedestal grinder) or for producing large quantities of dust (such as the foundry knock-out). As a preliminary to this programme, an exhaustive investigation was made into the formation and raising of dust, and the influence of thermal currents and cross draughts on its dispersal.

The work has now been completed and data have been established for various kinds of knock-out on the basis of which the air movement and velocities required to control the dust produced can be accurately assessed. A great deal of the experimental work involved was carried out during the period in which the new melting shop was unoccupied. When the new laboratory for the foundry atmospheres section is ready, the work will be carried further. Field investigations are to be made of dust collectors used by foundries and data will be collected for statistical analysis. The results, it is hoped, will help to solve the clean air problem and assist in providing specifications necessary for dust control within the foundry.

Research into Boiler Circulation Theory

No. I

Co-operation between the Water-Tube Boilermakers' Association and Cambridge University has led to the erection of the research equipment illustrated alongside. Its object is to establish experimental data about the pressure drop and flow conditions of a steam-water mixture flowing along heated and unheated pipes up to the critical pressure of steam. Here the equipment is described. Certain heating and measuring devices developed for the project are likely to find application elsewhere.



THERE is now in use on an open-air site within a disused aircraft factory on the outskirts of Cambridge, a research set-up whose object is to establish experimental data about the pressure drop and flow conditions of a steam-water mixture flowing along heated and unheated pipes up to the critical pressure of steam, 3206 lb per square inch. Studies are being made of the effect of several variables, including pressure, heat input rate, internal diameter of the test section, velocity of water entering the heated test section and the dryness fraction of the emergent steam-water mixture. To permit control over certain variables, assisted circulation has been adopted so that the velocity of the flow is independent of heat input. The arrangement also permits direct determination of the friction coefficient through the circulation of hot water alone prior to tests under conditions of steam generation.

This, at first glance, somewhat peculiar site for an elaborate research equipment was chosen partly because there is a certain safety factor about having high-pressure equipment in the open air. Electrical power supplies are readily available at the site. Erection of the supporting structure and pressure parts was begun in 1953. But delays occurred before the equipment came into use because to attain the desired precision in measurement it was found necessary to design and develop in the engineering laboratories at Cambridge University special induction heaters, differential thermocouples and differential manometers for use at elevated pressure levels. Certain research work has, however, since been completed and the results have been circulated to members of the Water-Tube Boilermakers' Association which has sponsored this work undertaken by Cambridge University. We understand that in due course the results will be published.

Fig. 1—Circulating pump and main control valve

Background to Project

The project for the erection of the equipment was initiated in the following way. In 1950, the attention of the Water-Tube Boilermakers' Association was drawn to certain experimental work being undertaken by the Department of Engineering in the University of Cambridge. This work, started the previous year, was confined to a simple U-circuit at atmospheric pressure, without steam production in the riser, and was related to some theoretical studies which were being made on the rate of circulation in a simple boiler circuit. These studies resulted in a unification of the existing, but previously conflicting, theories on the subject known as the "hydraulic," "thermodynamic" and "expansion" theories of circulation. This theoretical analysis was published in a paper entitled "Research into the Fundamentals of Boiler Circulation Theory," by R. W. Haywood, presented to the General Discussion on Heat Transfer, organised jointly by the Institution of Mechanical Engineers and the American Society of Mechanical Engineers, and held in London in September, 1951.

The paper was deliberately confined to a study of circulation theories which were based on the assumption that the steam-water mixture moved as a homogeneous fluid, because there existed a number of conflicting theories all of which took this assumption as their starting point. It was the purpose of the paper to show how these differences could be resolved. The assumption is known to be questionable, but its use is usually justified by the resulting simplification in a theoretical approach to the problem of circulation. In the conclusions to the paper attention was drawn to the limitations of the experimental work undertaken at Cambridge, in that, in the absence of steam production, it was not possible to study the effect of relative velocity between the steam and water phases of a steam-water mixture. This

phenomenon, commonly called bubble slip, is known to exist under actual flow conditions in a boiler circuit. It was consequently indicated that there was a need to establish experimentally further data relating to pressure drop, and to the conditions of steam production, at pressures used in industrial plant.

Following a report from technical representatives of member companies of the Association, who visited the Cambridge Engineering Laboratories to study the work, and after consultation with Professor J. F. Baker, the Head of the Department of Engineering at Cambridge, the Association agreed to sponsor an experimental research project proposed by the University as an extension to the existing work. A research contract was accordingly entered into with the University in 1951. Under the terms of this contract it was agreed that the Association should provide the high-pressure drum and pipework, together with their structural supports, and this equipment was supplied, delivered and erected by a member company.

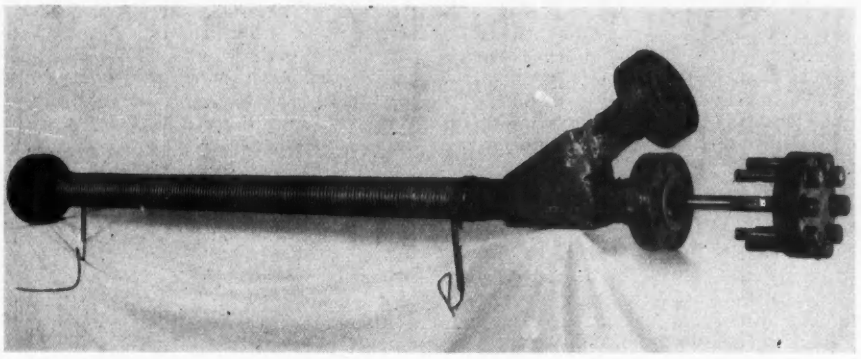


Fig. 3—Method of winding preheater and reheater. Immersion heaters are used for fine control

A Technical Advisory Panel, including representatives of the Department of Engineering and of the member companies of the Association, advised on practical and technical problems arising during the development stages, and planned the scope of the proposed test programme. The project, however, falls under the general supervision of Professor W. R. Hawthorne, Professor of Applied Thermodynamics, and is directed by Mr. R. W. Haywood, a University Lecturer in the Department of Engineering. The Association was afforded the opportunity of proposing suitably qualified nominees from the staffs of member companies, from among whom the University selected Mr. J. R. S. Thom to assist in the workshops and laboratories of the department during the design and development stages, and to assume the responsibility of operating the plant in the subsequent research investigations. One of the department's own graduates, Mr. G. A. Knights, later returned to the University to work on the project and has been appointed to the staff of one of the member companies of the Association and seconded to work at Cambridge. Numerous research assistants, whose services have been provided by the member companies of the Association, have been seconded to the Department of Engineering to assist in the research for periods normally varying between three and twelve months.

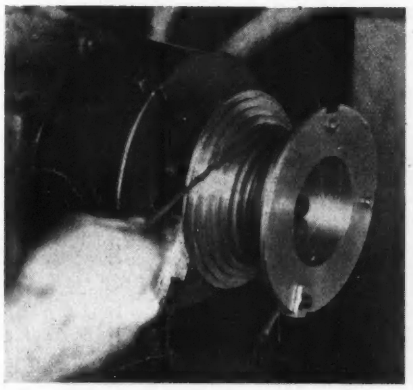
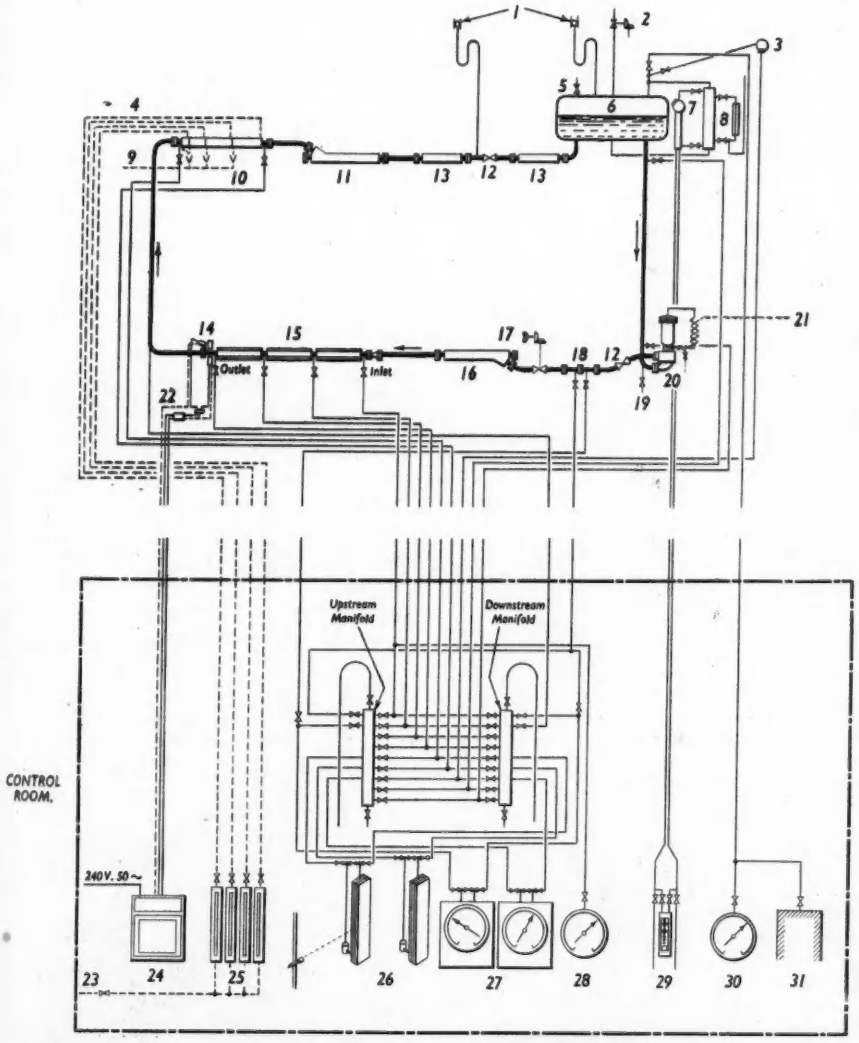


Fig. 4—Induction coils were wound on this jig, the outer section of which can be detached to allow the coil to be removed



1.—Rupture discs.
2.—Emergency blow-off and air vent operated from control room.
3.—Constant head chamber.
4.—Condenser cooling water (via flowmeters in control room).
5.—Filling connection.
6.—Steam and water drum.
7.—Constant head chamber and water bottle for remote liquid level indicator.
8.—Gauge glass (low pressure) for filling only.
9.—Discharge to drain.
10.—Calorimeter condenser.
11.—Reheater (hand controlled).
12.—Emergency valve (automatic closure).
13.—Drum heater (hand/automatic control).
14.—Gamma ray device.
15.—Electric induction heaters surrounding test section.
16.—Preheater (hand controlled).
17.—Flow control valve (operated from control room).
18.—Metering orifice.
19.—Blowdown valve.
20.—"Electromersible" pump, 60ft head, 53 g.p.m.
21.—Cooling water (town supply).
22.—Head amplifier.
23.—Cooling water (town main).
24.—Vibrating reed electrometer and recording unit.
25.—Flowmeters (cooling water).
26.—Differential pressure manometers.
27.—Differential pressure gauges.
28.—Pressure gauge (inlet to test section).
29.—Remote liquid level indicator.
30.—Pressure gauge (drum).
31.—Automatic pressure control.

Fig. 2—Diagram of the test equipment

General Description of Test Circuit

The test-section consists of a single pipe 24ft in length, equipped with heaters designed to permit heating over 8ft, 16ft or 24ft as desired. This allows the pressure drop in the unheated pipe following the heated part to be measured. The arrangement is such that the test-section can be set horizontally, vertically, or at any desired angle. Only 1in internal diameter pipes have so far been used for the test-section.

Water in the saturated condition from a steam drum (6) is circulated—see Fig. 2—by

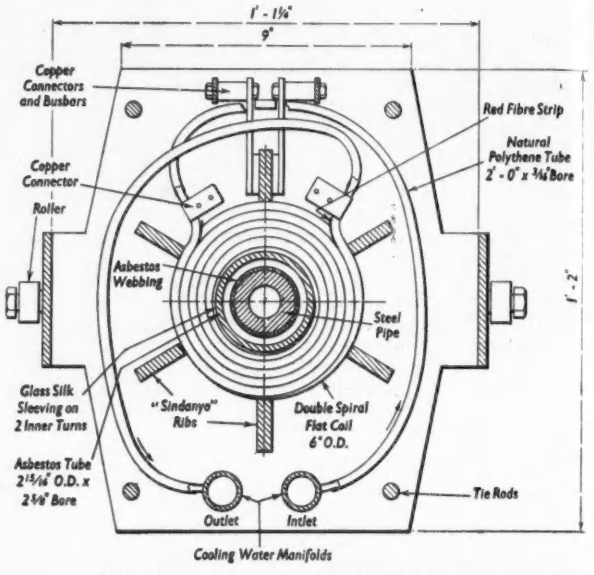
an "electromersible" high-pressure pump (20) in a closed system. The rate of circulation is measured by a standard orifice assembly, and is regulated and maintained constant by adjustment of a control valve. An electrical "Pyrobar" immersion pre-heater (16) is used to ensure that the fluid enters the inlet of the heated test-section (15) at exactly the saturation temperature corresponding to its pressure at that point—thus offsetting heat losses in the pump and connecting pipework and the effect of pressure difference between the test-section inlet and the steam drum. Accuracy is achieved by measuring carefully the differential pressure between the test-section inlet and the drum, and then adjusting the differential temperature—which is measured directly by accurately calibrated thermocouples of high sensitivity—to correspond to this pressure difference. Consequently, steam generation begins exactly at the inlet and takes place along the entire heated length of the test-section. To the test-section outlet there is connected a short 1ft length of alloy steel tube, the contents of which are scanned by a gamma-ray beam from a small capsule containing a radioactive isotope of caesium (14). By this means the density of the contents of the pipe is measured. On leaving the test-section the steam-water mixture enters a water-jacketed condenser (10) the purpose of which, it will be appreciated, is to remove the heat absorbed in the test-section, since no release of steam from the drum is desired, The condensate finally passes through an electrical re-heater (11) which restores the water temperature approximately to that of saturated steam before returning to the drum. Constancy of the operating pressure is maintained by combined adjustment of the quantity of condenser cooling water and the electrical input to the re-heater. The diagram shows how and where various measuring instruments are connected to the circuit and indicates also the positions of certain safety devices and of heaters (13) for the initial heating of the circuit and the maintenance of drum temperature when no test is in progress —Fig. 3.

Complete automatic control of the circuit is not intended, and the tests have been regulated entirely by manual adjustment. Thermocouples are installed at various parts of the circuit. These will, if required, supply direct readings of temperature in the usual manner, but where temperature differences are more important the individual couples are connected in opposing pairs to give differential readings, thus saving time and also reducing the observational error in the readings. Thermocouples are also "peened" into the outer surface of the test-section tube wall in order that a check may be kept against overheating of the tube. In the picture at the head of this article, the test-section can be seen in the horizontal position on the left. The main storage drum is easily picked out and at ground level close to the downcomer the circulating pump can be seen. This pump is again illustrated in Fig. 1. The large valve seen in the illustration is an emergency shut-off valve. Another similar valve is inserted in the circuit about half way round. Their object is to limit the outflow of steam and water to that contained in only one half of the circuit should anything untoward occur.

Detail Design

Method of Heating.—Various alternative methods of heating the test-section electrically were considered, the main requirements being ease of control and uniform heat absorption per unit length of pipe. Low-frequency induction heating was finally adopted as it did not require electrically-insulated high-pressure joints and was adaptable to three-phase heating for increased heat inputs. It has proved, we are informed, admirably suited to the purpose. Very little information was available on this type of low-frequency induction heating and much preliminary work—itself in the nature of a fundamental investigation—had to be done to establish what heat input rates were possible—very high rates were needed to simulate boiler tube conditions. The results of this investigation are expected to be of value in other applications in addition to having a direct bearing on the present research. The heaters were designed and constructed in the engineering department of the University in consultation with Wild-Barfield, Ltd., a firm which holds a patent on a certain feature of the water-cooled windings. The design finally adopted permits the power supplied to be varied over a considerable range in a number of steps without the use of an expensive voltage regulator.

The principle of induction heating is to wind a coil round the tube to be heated, and by applying an alternating current to the coil, to produce a magnetic field, which induces electrical currents round the circumference of the tube. The high grade steel used for the manufacture of the tubes is not ideal for high-intensity electrical loading, but by spraying the outside of the tubes with copper approximately 0·05in thick, an extra electrical conducting path is made available, which greatly increases the possible loading. There are mounted on the test-section six of



To operate on 140V or 415V, 50 cycle a.c. mains. Maximum heat rate about 120,000 B.Th.U. per square foot per hour through outer surface of 1in bore, 1¼in outside diameter M.S. tube, corresponding to 16·1kW per foot.

Fig. 6—Cross sectional view of induction heating unit

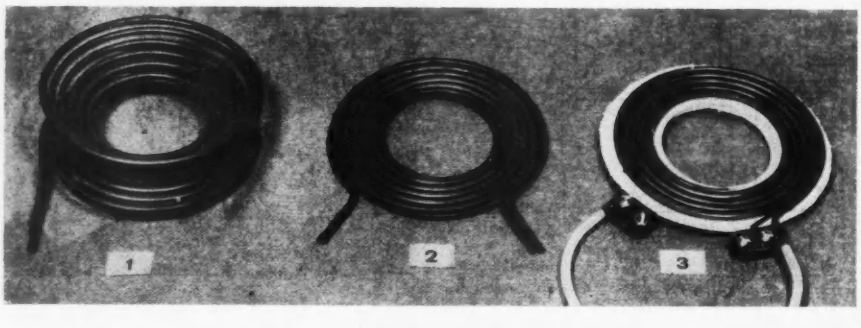


Fig. 5—Three stages in making a coil. On the left the coil is seen as it comes from the winding jig; on the right the coil is shown mounted on insulating material with polythene tubes attached

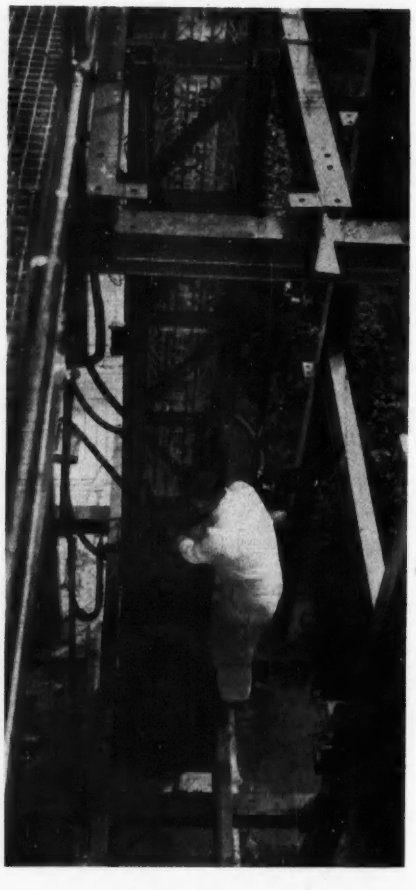
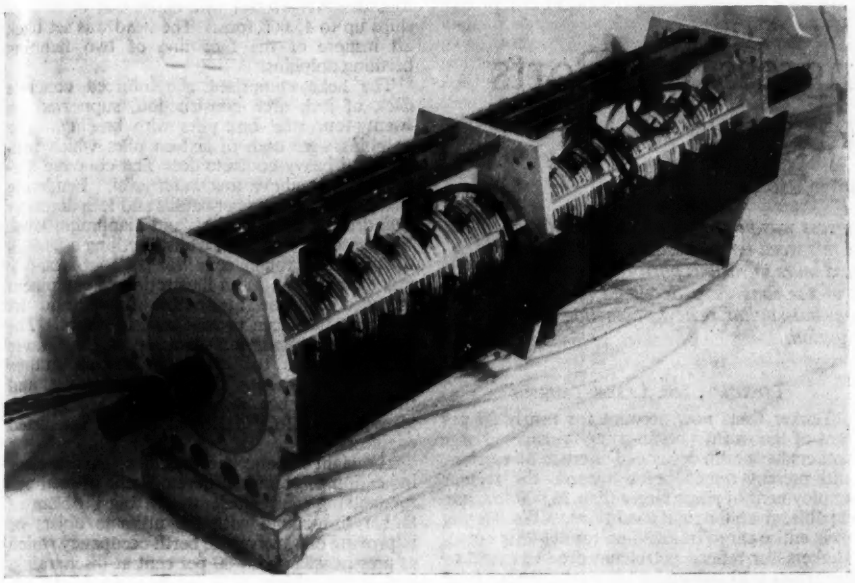
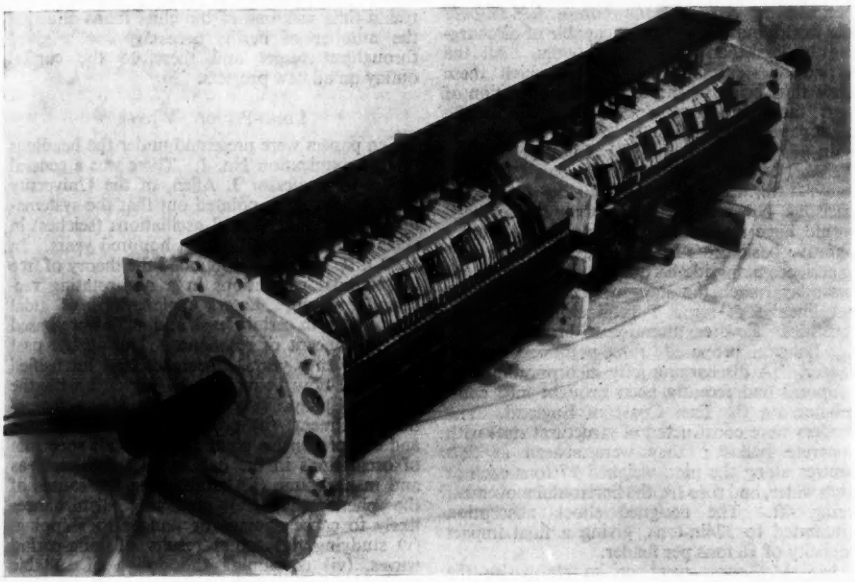
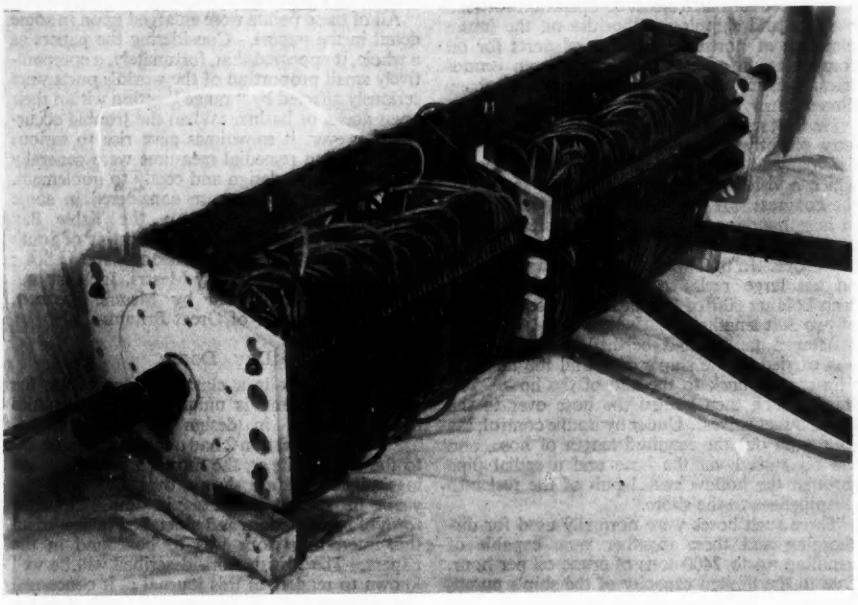


Fig. 7—The test section, here arranged vertically, is seen from the top platform







Figs. 8, 9 and 10—Three stages in the assembly of a heating section are shown. At the top electrical connections from the coils can be seen brought out from the coils. Busbars allow coils to be connected, as desired, in parallel or series. The middle view of the assembly shows the inlet and outlet water manifolds. Below this is a competely assembled heating section with the polythene tubes from the coils connected to the manifolds

these induction heating units, each of which is 4ft long. Each unit is divided into six sections, each of seventeen coils, the coils being made from lengths of high-conductivity copper tubing. Tubing was chosen because though the steam-water mixture flowing through the test-section is heated by currents induced in the steel tube and the copper coating upon it, the induction coils have themselves to be cooled. The use of copper tubes for the coils permits water to be circulated through them.

The method of winding the coils of copper tubing is illustrated in Fig. 4. As the winding jig is made in two conical halves the removal of the outer half allows the wound coil to be removed without taking the inner part of the jig out of the chuck. Subsequently the coil, which has $11^5/_6$ turns, is flattened by the simple process of laying it on a flat surface and heating it. A disc of insulating material is interposed between the two halves of the coil—Fig. 5—and a strip of red fibre is wound in to insulate each turn from those next to it. Figs. 8, 9, 10, and 6 show how the coils are mounted up into assemblies around the tube through which the steam-water mixture flows. In the first of these illustrations it can be seen how electrical connections are made from the coils. Each of the six heating sections within a single heating unit— two such units form a complete assembly as seen in the photograph—can be connected in any wanted way, series or parallel, with the others, from busbars extending along each heating section. Fig. 9 shows the inlet and outlet water manifolds extending along the unit, and in Fig. 10 the polythene tubes from the various separate coils are seen connected up to the manifolds. Fig. 7 shows the fully assembled test-section in the vertical position.

(*To be continued*)

Mechanical Engineering Research

THE Reports of the Mechanical Engineering Research Board and of the Director of Mechanical Engineering Research for 1956 have now been published. During the year the staff of the Mechanical Engineering Research Laboratory at East Kilbride increased in numbers, but the improvement was qualified by the lower level of experience of the new arrivals.

Various approaches have been made to the problem of measuring very large liquid flows. An equipment to scan up to twenty-one propeller current-meters, and observe the flow rather than the quantity passed, has been developed. Other techniques are the salt-velocity and salt-dilution methods: the first observes the time interval between the increases in conductivity at two points at a known distance apart as an injection of salt water is carried along the stream. The second uses a salt such as sodium dichromate, which is not present in natural water and can be estimated to 1 part in 100,000: it is fed into the flow at a constant rate and assayed far enough downstream for its distribution to be uniform.

Investigation of problems concerned with lubrication is again prominent and both fundamental and *ad hoc* work on scuffing is recorded. The tests on extreme-pressure lubricants are carried out, like those of the Inspectorate of Fighting Vehicles (see page 56, July 13, 1956), on Standard back axles, but a rig circulating power through the differentials of a pair of axles, one being loaded in reverse, has been installed.

The properties of possible matrices for regenerators are to be measured in a new equipment which passes a current of air into the sample material at a temperature varying sinusoidally in time. Successful techniques to improve heat exchange through condenser tubes by promoting drop-wise condensation are also reported: some of the substances applied to the metal are not permanently harmed by exposure to air, and application to a cross-channel steamer proved successful. On a power station set used for peak chopping, success was qualified not only by air, but also by formation of rust.

International Congress on Ports and Waterways

No II—(*Concluded from page 56, July 12*)

The nineteenth international navigation congress was in progress at the Institution of Civil Engineers in London last week, and this week until Tuesday. Many of the delegates are now taking part in post-congress tours in various parts of the country. Our account last week reviewed the work of the congress's Section I, on inland waterways. Here, we continue with a somewhat similar review of Section II, on ocean navigation.

FOLLOWING once more the official titles of the various subdivisions of the congress's technical work, we have in the second section, which covered ocean navigation, two "questions" and three "communications" as follows:—Question 1: measures to be taken for improving the handling of general cargo between the vessel and the storage installations on the quay or between the vessel and the means of inland transport, and vice versa. Question 2: berthing of large oil tankers; handling of their cargoes; pipeline layout and hose handling equipment for loading and discharging tankers; provision of facilities for distribution by road, rail or smaller vessels; measures to be taken for ensuring safety; methods of preventing or reducing pollution of harbour waters; equipment for gas freeing and cleaning the tanks of oil-carrying vessels.

Communication 1: origin and effects of long-period waves in ports; precautions to be taken for the safety of vessels; possibility of minimising the effects; experiments using scale models. Communication 2: maritime locks and graving docks (dry docks); calculations of modern methods of construction; types of gates and caissons; stresses to which they are subject; designs adopted specially for those which are exposed to swell. Communication 3: siltation in coastal waters, in estuaries, in channels, in tidal basins, in enclosed docks and in maritime canals; methods for minimising it; modern methods of measurement of depths, currents, waves, tides and silt movement in coastal waters and in estuaries.

There was also a paper entitled "Reflective Signs for Day and Night-Time Navigation," by Commander T. Stranger-Johannessen, of Norway, which did not fall within the general scheme of classification.

Cargo Handling

The terms of reference for Question 1 embrace a subject of considerable importance to the general economy of any country; much attention has been paid in recent years to discussing methods of improving cargo handling, and, hence, reducing the time which a ship must spend in port. At the congress ten papers were presented, giving altogether a thorough examination of this problem; some dealt with only restricted aspects and others gave detailed analyses and comparisons of various phases of cargo handling.

The views of the American author are worthy of mention. He pointed out that the transfer of cargo between ship and shore was still carried out by methods substantially the same as in the past, and ports had not kept pace with the development of ships, so it had not been possible to exploit the full use of modern shore cargo handling appliances and new packaging techniques.

Despite other possibilities, this author maintained, the most important requirement was that of a co-operative labour force willing to develop craft and techniques which, in association with modern handling gear, would increase productivity to an extent which would provide the demand for improved facilities.

In the paper presented by the Soviet delegation, international action and regulation was suggested, the measures possible by individual port authorities being considered too limited. The aim would be complete mechanisation of cargo handling.

Berthage for Large Tankers

Tanker fleets now account for nearly 30 per cent of the world's ocean-going tonnage. Large tankers have been developed as crude oil carriers, and present trends point towards the regular employment of ships larger than 30,000 tonners, capable, given the right conditions, of discharging their entire cargo in less than twenty-four hours. Tankers for refined petroleum products tend to be between 10,000 and 18,000 tons deadweight, because they have to trade more or less all over the world, but they, too, are capable of discharging in less than twenty-four hours. All the varied and specialised problems which these craft thus bring to the design and operation of port facilities, were expounded upon in the eight papers in Question 2.

In his general report for Question 2, Mr. C. W. N. McGowan, of the Kuwait Oil Company, Ltd., expressed the opinion that comparisons between different forms of berthage would have had even greater weight had comparative basic costs been included. In his own experience alongside berthing construction could nowadays reach the staggering figure of £2000 per lineal foot for a T head alone in certain localities. He drew attention to Professor A. L. L. Baker's proposed three-point suspension fender. A discharging jetty incorporating that proposal had recently been brought into commission on the East Coast of England. The fenders were constructed of structural steel with concrete ballast; they were spaced at 26ft centres along the pier, weighed 27 tons each at high water, and rose 1ft, the horizontal movement being 4ft. The designed shock absorption amounted to 324in-tons, giving a final impact capacity of 16 tons per fender.

Mr. McGowan went on to emphasise the urgent need for much closer co-operation between harbour and shipping authorities on the future planning of ports, in the case of ports for oil companies in an effort to preserve an economical balance as between tanker and berthage dimensions.

He then mentioned the new tanker discharging jetty recently commissioned by the Mobil Oil Company at the Coryton refinery in Essex, to which a visit had also been arranged as part of the congress. It incorporated a major advance in hose handling and, indeed the hose structure was, as far as he knew, the only one of its kind in Europe. In that system the hoses were wound on ten large reels, each 18ft in diameter and each holding 60ft of 8in diameter hose made up of two 30ft lengths.

After a tanker had berthed a snatch-block was carried to the ship's deck and the tail of a wire carried back to the end of the hose. The ship's winch then hauled the hose over to the ship's outlet valves. Under hydraulic control, the reels paid out the required length of hose, and the oil passed via the hose and a radial pipe through the hollow swivel hub of the reel into the pipelines to the shore.

Three such hoses were normally used for discharging and these together were capable of handling up to 2400 tons of crude oil per hour. Due to the limited capacity of the ship's pumps that figure had never yet been reached. The remaining seven hoses were employed in loading tankers with products from the refinery such as gasoline, gas oil, diesel oil, bunkers, &c.

The jetty itself was of T head construction, designed to accommodate tankers of 33,000 tons deadweight and with extensions in view of ships up to 45,000 tons. The head was set back 2ft inshore of the face line of two flanking berthing dolphins.

The head comprised a reinforced concrete deck of jack arch construction, supported on twenty-four steel box piles with bracing. The dolphins were each of sixteen piles which supported a heavy concrete deck and concrete diaphragm just above low water level. Fendering was provided by timber baulks and 15in diameter cylindrical fenders at deck and diaphragm level. These proved successful whilst berthing a 28,000-ton vessel in rough conditions. That example was merely given as an illustration of equipment intended for the foreseeable future and its efficiency had been proved beyond doubt. The multiple hose-carrying gantries at Le Havre and Marseilles to which the French author had referred, were of considerable interest, and their performance would, in Mr. McGowan's view, be carefully followed by all interested engineers.

The eight papers, he concluded, gave a clear indication of continual development in methods for tackling more efficiently the big problem of tanker turn-round with the ultimate object of improving on the average berth occupancy which at present was about 60 per cent at discharging, and slightly higher, at loading points. Turn round time was one of the chief items affecting the number of berths necessary for a given throughput target and therefore the capital outlay on all new projects.

Long-Period Waves

Ten papers were presented under the headings of Communication No. 1. There was a general report by Professor J. Allen, of the University of Aberdeen, who pointed out that the systematic study of long period oscillations (seiches) in lakes went back well over a hundred years. In 1828 J. R. Merian propounded the theory of free longitudinal oscillations in a non-rotating rectangular basin. Later, explanations of tidal phenomena in certain bays and gulfs were based on the concept of resonance. During the past ten or twenty years, researches had intensified and were now being pressed forward with the object of (i) improving or extending the mathematical treatment, (ii) providing a more accurate and comprehensive picture of the wide spectrum of oscillations in the oceans, in shallower seas and in harbours, (iii) establishing the causes of the phenomena, (iv) predicting disturbances likely to cause damage or danger to shipping, (v) studying the actual results of long-period waves, (vi) developing the design of suitable alleviating and remedial measures.

All of these points were enlarged upon in some detail in the papers. Considering the papers as a whole, it appeared that, fortunately, a comparatively small proportion of the world's ports were seriously affected by "range" action within their open docks or basins. When the trouble occurred, however, it sometimes gave rise to serious problems and remedial measures were generally both difficult to design and costly to implement.

Two famous cases were considered in some detail by different authors: the Table Bay Harbour of Cape Town by Mr. Joosting of South Africa and by Dr. B. W. Wilson of the U.S.A.; the Harbour of Madras by Messrs. Joglekar and Kulkarni of India and by Messrs. Deacon, Russell and Palmer of Great Britain.

Dry Docks

The dry dock is a classical exercise for the civil engineer, and is unique in the difficulties it offers, both in design and construction. Thus Communication 2 had a considerable appeal to the civil engineer, the more so because much ingenuity has been shown over the past few years in several countries in improving this form of construction, and a detailed review of all this interesting work was to be found in the papers. The British work described will be well known to readers of this journal; it concerned the entrance lock at Eastham Oil Dock, and the two new dry docks of novel construction recently built on Tyneside. The following brief account of work in some of the countries which submitted papers at the congress, together with some generalisations about the papers as a whole, has

been abstracted from the general report of Mr. J. H. Jellett, M.I.C.E., the British Transport Commission's docks engineer at Southampton.

Western Germany.—Of the five dry docks described in the West German paper, four are remarkable for their unusual width, namely 60m or nearly 200ft.

The dock at Bremen is not designed to resist hydro-static uplift, which is cut off, as far as possible, by an enclosing curtain of steel sheet piling driven below formation level. The dock floor itself is vented for the relief of any hydro-static pressure which might nevertheless tend to develop, but in spite of this a thickness of 4m or about 13ft was necessary to meet the high keel loads which varied between 150 tons and nearly 400 tons per foot run. There is no mention of the type of gates it was intended to use for this dock.

The floor of dock No. 7 at Wilhelmshaven is designed as an inverted arch to resist hydro-static uplift, and the floor is extended beyond the walls on each side to obtain additional assistance for this purpose from the overlying soil and to provide support for buttresses to carry the landward crane rails. The dock is divided by fifteen transverse and three longitudinal joints, all securely waterproofed, and the four sections into which the latter divide the work comprise broadly the two halves of the floor on either side of the centre line and the two walls, which were constructed in advance to allow settlement to take place.

Dock Elbe 17 at Hamburg is also designed to resist hydro-static uplift, the floor acting as a beam spanning between the heavy side walls, for which purpose it is reinforced as required and also to carry the heavy centre keel loading of nearly 400 tons per foot run. The structure is divided by fifteen transverse and three longitudinal joints suitably waterproofed.

In the case of dock No. 8 at Wilhelmshaven, venting of the floor was ruled out by the size of the pumping effort this would have involved and the risk that resulting ground shrinkage might cause damage to property in the town. On the other hand, a dock structure heavy enough to resist hydro-static uplift by its own weight would not have been an economic proposition. It was therefore decided to anchor the floor by piles driven on a sharp rake so as to secure the maximum value from the weight of the ground intervening between adjacent piles. The side walls, 13ft thick, are supported on 26ft wide footings founded between lines of steel sheet piling, and are anchored back through a continuous projection extending about 30ft from the back of the wall to a double line of raking piles. This projection also serves to carry the supports for the inner crane rail. The work was divided by longitudinal and transverse joints as in the cases already described, and was intended to be closed by a box shaped ship caisson but the construction was never carried to completion.

The dock at Emden, of considerably less width —about 105ft—than those previously described, is nevertheless of considerable interest in that prestressing techniques were used to anchor the floor to the underlying ground ; 496 steel wire anchor cables stressed up to 105 tons each secure the dock to as many reinforced concrete anchor plates sunk into the ground by means of vibration. Additional consolidation of the ground round the anchor plates is achieved by special compaction cores also sunk into the ground by vibration. Provision is made in the arrangements for securing the cables to the concrete floor for the tension in the cables to be examined at a later date and increased if necessary. The gate is a ship caisson.

Denmark.—This paper describes three new dry docks of interesting and widely different design and construction. The first at Copenhagen designed to take tankers up to 38,000 tons deadweight, was carried to an advanced state of construction without de-watering the site. The walls, which were constructed first, consist of precast reinforced concrete caissons manufactured on an adjacent site and floated into place by special equipment. The sea bed over the area of the dock having been dredged, the caissons were sunk in position and filled with concrete deposited under water by tremie pipes to a level sufficient to enable them to resist buoyancy. They were then pumped out and the remainder of the concrete work on the walls was carried out in the dry. The walls constructed in this manner were then used to support two travelling gantries carrying respectively arrangements for setting the steel shuttering used for casting successive bays of the floor slab, and the arrangement of tremie pipes used for pouring this concrete. Ready mixed concrete from a factory in Copenhagen was delivered in agitator trucks approaching along one side wall and returning by the other.

The dock was not pumped out for the first time until after the gates had been placed in position and it was then found to be leaking slightly through the joints between the successive sections of the floor slab. When the leaks had been remedied a layer of mass concrete about 1ft 6in thick was laid over the whole floor.

Being founded on a fissured limestone rock, the dock is subject to full hydro-static uplift and the floor and walls are designed on this basis, account being also taken of the alternative loading imposed by a ship in the dock. No calculations were submitted, but it was stated that the tensile stresses in the concrete would not exceed 140 lb per square inch, and it was assumed that the concrete was of sufficiently good quality to resist that.

The gate is a horizontally hinged flap, similar to the " Box " gate, operated by two electric winches. The pumping out of three compartments normally filled with water ballast enables the gate to float for docking. Watertightness is effected by rubber strips secured to the face of the gate.

The second dry dock is at Nakskov and is designed to take ships up to 20,000 tons deadweight. As this site consists of impermeable clay to a considerable depth, the design assumes that it will not be necessary to resist hydro-static uplift, and any possibility of this developing is eliminated by the provision of drains in the floor and walls. The dock is constructed in reinforced concrete, the slenderness of the side walls which are anchored back with steel ties being indeed remarkable. Flexible joints are introduced between the floor slab proper and the slab footings of the walls so that the settlement of the floor under docking loads will not in any way affect the walls. The strength of the floor slab has been calculated by successive approximations carried to the point at which the deflections of the slab at the centre and edges are brought to be equal to the elastic deformation of the sub-soil at the same points. It is then assumed that this coincidence will be sufficient to bring the curves of deflection and soil deformation into line throughout the width of the slab. The dock gate is similar to that already described for the dock at Copenhagen.

The third dry dock is at Elsinore and is designed to take ships up to about 12,000 tons deadweight. As it is founded on water bearing sand and gravel overlying the limestone rock, full hydro-static uplift has been allowed for, but economy has been achieved in the thickness of the walls by extending the floor slab a distance of some 12ft beyond the back of the walls and using the weight of the earth overlying this extension in place of the concrete so frequently provided in mass concrete gravity walls.

To keep the excavations free from water during construction, it was necessary to surround the site with steel sheet piling and put down some 400 well points. The method of construction is also interesting by reason of the use made of the partly demolished structure of a previously existing dry dock which was employed as a shoring base to support the steel sheet piling until the construction of the side walls had proceeded far enough to enable them to take over this function.

The dock gate is a floating caisson stabilised partly by concrete ballast and partly by water ballast. The water ballast tanks can be emptied by compressed air from the shore supply and by this means the flotation of the caisson is controlled.

France.—The construction of maritime locks in recent years exhibits a widespread change in favour of the use of steel sheet piling for the walls, with concrete construction confined to the head and tail structures, the floor being permeable or omitted altogether. Occasionally, mixed systems of concrete and steel sheet piling may be employed for the walls as an alternative. Examples briefly described include two locks at Dunkirk, one projected at Caen-Ouistreh and one at Dieppe.

Two sets of sector gates are described, one at Dieppe and one at St. Malo, and reference is made to the features of this type which enable the gates to be opened in bad weather or against a head of water, although the lock at St. Malo is not seriously exposed to swell. Interesting features of the gates at the latter lock include stainless steel roller bearings immersed in oil with a mercury bath seal ; the prestressing of the anchorage foundations to avoid tension in the concrete under the worst conditions of loading ; and the rubber shock absorber in the operating chain which also acts to cut off the power supply in the event of overloading. In both the above cases, watertightness is assured by the use of inflatable rubber seals.

Dry dock gates generally take the form of ship caissons whose superior simplicity and robustness outweighs their relative slowness of manœuvre, a drawback which is of less importance with dry dock gates than it is with lock gates. Examples are quoted at Brest and Cherbourg where rolling gates have been replaced by ship caissons. At St. Nazaire there is a particularly novel design of ship caisson which by offering a concave surface to the opposed water pressure is stressed in tension throughout, whereby, it is stated, considerable economy of material is achieved.

Italy.—The Italian paper describes the design and construction of two dry docks, one at Trieste and one at Naples. The construction at Trieste is of particular interest by reason of the fact that half of its length being founded on impermeable rock, is not subject to hydro-static pressure, while the other half, owing to the steep decline of the rock stratum in the length of the dock, is founded in permeable material and has to be designed to resist full hydro-static pressure. Two completely different designs of structure are therefore apparent in the two halves of the dock. The seaward half under which the permeable material occurs, was prefabricated in reinforced concrete cellular construction, in two sections which were floated out and sunk on to foundations consisting of cylinders driven by the Benoto process down to the firm rock. These sections were fabricated in a basin formed from the excavation for the landward half of the dock, the part overlying the firm rock, which was surrounded for the purpose by a cut-off wall of concrete sheet piling. The entrance to this basin was closed by a special concrete caisson provided to effect the junction between the two forms of construction in the dock and sunk in position under compressed air at the commencement of operations. The opening in this caisson corresponding to the normal section of the dock was temporarily closed by a cofferdam of steel sheet piling filled with sand, which had to be constructed three times for the successive operations of building the two prefabricated elements of the seaward end and the final completion of the landward end.

It will be appreciated that the structurally most interesting portion of the dock is the section formed of the two prefabricated elements and a considerable portion of the paper is devoted to a detailed description of these and of the foundation cylinders on which they are supported. These cylinders are in four rows, two under the centre of the floor and one under each of the side walls.

Conclusions.—The general reporter is not expected to draw firm conclusions from the papers presented, but there are one or two features of these papers taken as a whole which might be worth comment. Dealing with the design of gates, it is noted, for example, that in the paper from America, the change over from uni-directional to two-directional systems of pressure distribution is offered as a means of economising in material. By contrast, in the paper from West Germany, the change in the reverse direction is presented as a means of reducing the complication in the computation of the stresses in the gates. Some resolution of the conflict between these two suggestions appears to be desirable.

With regard to the design of the dock structures themselves, this is so materially affected by the varying ground conditions which may be encountered on different sites, that the absorption

of some authors with pressures on the ground while others concentrate on the loads induced in the structure, provides a contrast in methods of approach which will probably continue for as long as docks are built.

Silting

The reporter for Communication 3, Mr. C. H. Dobbie, M.I.C.E., made the following general remarks as part of his general report.

The subject matter of this communication has an extremely wide range and the authors have availed themselves of it to the fullest extent. The papers are so diverse that no attempt has been made at a general summary or even to provide sub-headings. There is thus no substitute for the reading of the papers themselves. It has been found possible, however, to separate to some extent the subject into two parts—siltation and measurement. For measurement the methods and instruments used have been summarised. It is not anticipated that for this part of the subject any specific steps are likely to become universal, but some agreement may be developed as to the outline of future studies.

Siltation of ports is a classical problem which has affected the fate of empires. Now it has an immediate urgency due to the ever-increasing draught of vessels, and already the world expenditure on dredging is enormous. To all but dredging contractors this enormous expenditure is galling ; there is no visible return for the money, yet the very existence of many ports depends on these operations. There is also a general feeling that better measurement of silt movements and of the hydrographical factors involved must lead to a better understanding of basic siltation phenomena and ultimately to reductions in dredging costs. While siltation must always be a complex subject likely to defy very close analysis, the papers do illustrate the very great progress made in tackling the problem in many countries. Further progress is likely to come gradually from steady observation rather than by any spectacular step. It is tempting but rather optimistic to expect the magic of radio-active isotopes to bring quick or startling results, but at least their use must provide a very powerful new technique to assist the present difficult studies.

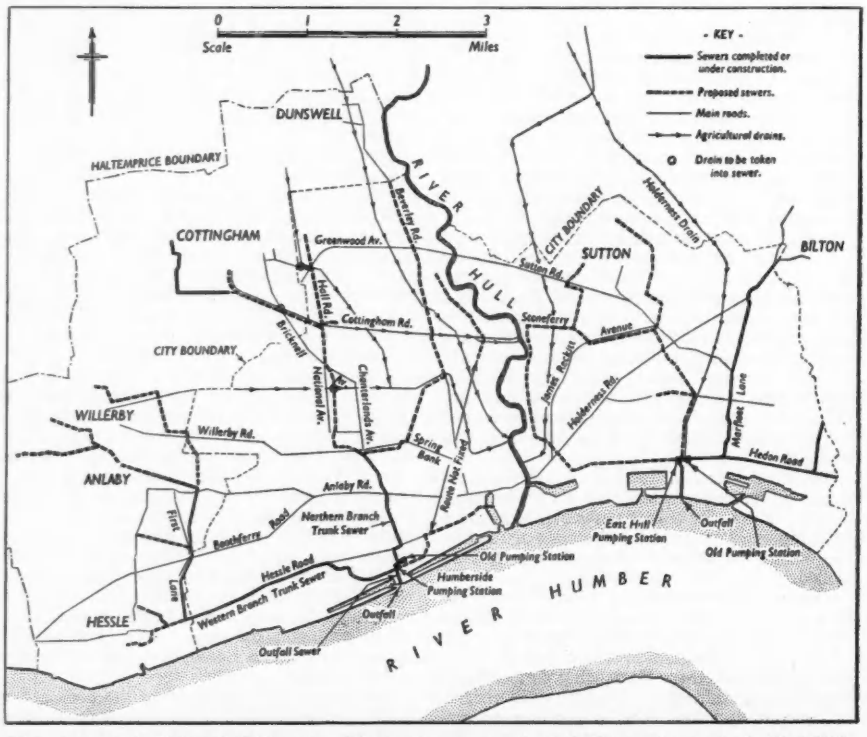
Main Drainage in the City of Kingston upon Hull

No. I

Reconstruction of the main drainage system of Kingston upon Hull has been in progress for a number of years. Most of the city lies below the high water level of spring tides, so pumping plant of large capacity is needed. The western part of the city and the adjoining urban district of Haltemprice are to be served by new trunk sewers and a large pumping station which is to be inaugurated next week. Here the general scheme and the sewer construction are described ; In subsequent articles we shall deal with the pumping station.

THE main drainage problems of Kingston upon Hull are, it is believed, without parallel in this country. Practically the whole of the city is below the level of high-water spring tides ; the catchment area is divided by the River Hull, which flows from north to south through the city and which itself creates a serious flooding problem from time to time, and the technical design is further complicated by the fact that the land, which forms a continuation of the Lincoln Marsh across the Humber, is to all intents and purposes flat. Thus, it follows that the sewers have, of necessity, to be of large diameter and have to be constructed in very indifferent subsoil and at considerable depth near the outfalls. The fact that no relief can be afforded in times of flood by storage means in effect that the pumping plant must be capable of handling the maximum run-off at all times.

A completely reconstructed main drainage scheme for the whole of the city and much of the adjacent urban district of Haltemprice was first conceived in the middle 1930s to replace the existing system which had been built generally between 1870 and 1900. No new work was started, however, until 1945 ; the eastern half of the city was given the first attention, and it was not until 1950 that constructional works were put in hand in the western part of Hull, on the West Hull and Haltemprice Joint Main Drainage Scheme. This scheme owes much in its design to the earlier works east of the river, so we propose to describe these eastern works first, and then go on to the West Hull and Haltemprice scheme in greater detail.



Main drainage in Hull and Haltemprice. The trunk sewers serving both districts (i.e. sewers in West Hull taking drainage from Haltemprice) and the Humberside pumping station comprise the joint scheme

Main Drainage Data for East and West Hull

East Hull Main Drainage

Works completed for area east of Holderness Drain. :	
Drainage area (east of Holderness Drain)	1846 acres.
Outfall sewer ...	Pumping station to River Humber. 9ft 6in diameter, length 650 yards, gradient 1 in 700, depth to invert 18ft to 29ft, capacity 35,000 cubic feet per minute. Completed 1947.
Pumping station	Completed with two pumping sets installed in 1950. Two further sets installed in 1953. Two 24in d.w.f. pumps each of 1600 cubic feet per minute capacity. Two 48in storm water pumps, each of 6400 cubic feet per minute capacity.
Sewers	6171 lineal yards diameter from 9ft to 18in. Depths to invert from 23ft to 10ft.
Old pumping station ...	Closed down in 1953. Three steam operated reciprocating pumps, each of 1100 cubic feet per minute capacity and two electrically operated pumps, each of 1600 cubic feet per minute capacity. The electric pumps now act as standby for the new station.

Works proposed for area west of Holderness Drain : still in preliminary stages ; figures given are approximate only.

Drainage area (west of Holderness Drain) 3400 acres approx. Approximately 15,000 lineal yards of 9ft 6in diameter to 3ft 6in diameter trunk sewers to be laid at depths to invert varying from about 9ft to 28ft.

West Hull and Haltemprice Joint Main Drainage

Drainage area in West Hull	7250 acres.
Drainage area in Haltemprice	3970 acres.
Total	11,220 acres.

To which must be added approximately 8400 acres of agricultural catchment area.

Works completed :	
Outfall sewer	Pumping station to River Humber. 10ft 9in diameter, length 327 lineal yards, gradient 1 in 408, average depth to invert 28ft, capacity 71,000 cubic feet per minute, 8in diameter screenings rising main from pumping station to River Humber. Completed 1953.
Western branch trunk sewer.	8ft diameter, gradient 1 in 1500, length 4650 lineal yards, depth to invert from 24ft to 34ft, capacity 15,400 cubic feet per minute. Completed 1956.
Under construction :	
Pumping station ...	Total capacity 63,000 cubic feet per minute against a head of 45ft to 50ft. Maximum depth excavated below ground level for substructure 64ft.
Northern branch trunk sewer.	10ft 9in diameter, gradient 1 in 1100, length 2320 lineal yards, depth to invert 26ft to 35ft, capacity 39,000 cubic feet per minute. Also 280 lineal yards of 9ft diameter sewer and 90 lineal yards of 8ft diameter sewer.
To be constructed :	
Northern branch trunk sewer.	1466 lineal yards, 9ft diameter sewer, 90 lineal yards, 4ft 6in diameter sewer. 1226 lineal yards, 8ft 6in diameter sewer, 355 lineal yards, 5ft 6in diameter sewer.

West Hull Main Drainage

To be constructed :	
Northern branch trunk sewer.	2074 lineal yards, sewer 7ft to 2ft 9in in diameter.

In addition there are further trunk sewers to be constructed, such as the Central Area Trunk Sewer for which only preliminary design work has been executed.

Average rainfall	22in per year.
Old West District pumping station.	Three steam operated reciprocating pumps, each of 2500 cubic feet per minute capacity and one electric pump of 3000 cubic feet per minute capacity.

Main Drainage in East Hull

The accompanying map clearly illustrates how the River Hull divides the city's main drainage into two separate areas ; the principal sewers and the two pumping stations of the new schemes are shown, and the information given in the table will give a general idea of the size and functions of the two drainage schemes.

Improved drainage was first desired in the eastern part of the city to enable new housing developments to be built. Thus new trunk sewers were built after the last war to the east of the Holderness Drain, giving an estimated initial maximum run-off of 7000 cubic feet per minute. The pumping station was commissioned

in 1950 with one dry weather flow pump and one storm water pump, to deal with the drainage from this area, and thus permit the building of houses for about 30,000 people (the city's population is about 300,000). The invert level of the new sewer was 16ft below mean tide level, so no gravity discharge was possible ; some measure of gravity discharge—for three or four hours at low water—was possible with the old pumping station, where the invert is about 6ft higher.

Two more pumps—one dry weather flow and one stormwater—were installed in 1953, when arrangements were made for the construction of a diversion sewer to enable the whole of the discharge into the old steam station to be diverted to the new electric station. The introduction of this additional flow did not introduce a prohibitive total throughput, since the quantity was limited by the size of the trunk sewers serving the area draining to the old station and which were known to be capable of contributing more than 3000 cubic feet per minute under the most favourable hydraulic conditions. Any further development of the trunk sewer system in this area would involve additional plant which would probably be at a lower level so as to serve a greater area of the hinterland, and operate on self-cleansing gradients and velocities; such development is envisaged in a few years' time when the West Hull and Haltemprice joint scheme is substantially completed.

No system of sewage treatment has ever existed in the eastern part of the city and the present development does not provide for any, though space is available should screening and maceration be incorporated at a later date. The pumps are, however, protected by 4in bar screens as a safeguard against the occasional planks or other foreign bodies which from time to time find their way into the trunk sewer system.

The pumps which were provided when the station was originally commissioned were vertical single-inlet-bowl screw machines. The minimum head (assuming minimum flow and low tide) is about 22ft and the maximum head (corresponding to full throughput of the completed station and highest recorded tide) is 42ft, but this maximum head will not be realised until the second pumping station, designed to deal with the run-off from the area between the Holderness Drain and the River Hull, is complete, and the outfall is being utilised to its full design capacity of 35,000 cubic feet per minute. The pumps were designed for an optimum efficiency at 28ft total head, but, if desired at a later date, it would be possible, by changing the impellers, to alter the optimum efficiency design point to 35ft, thus catering for the increase in frictional resistance on the outfall under the heavier throughput conditions which would ultimately obtain.

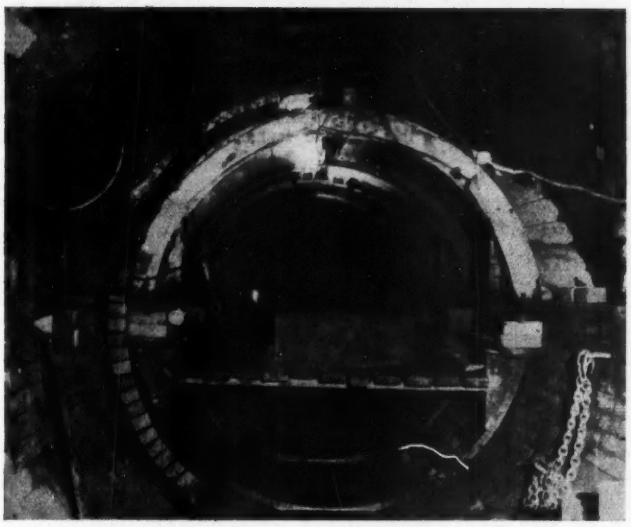
The optimum efficiency of the dry weather flow pumps is not less than 81·5 per cent and of the storm water pumps 82 per cent, and the combined efficiency of the pumps, motors and auxiliaries at normal duties is approximately 70 and 76 per cent respectively. The machines installed at East Hull run at 600 r.p.m. (dry weather) and 333 r.p.m. (storm).

All the pumps are in a dry sump, and each is fitted with a suction isolating valve and a gravity self-closing discharge valve, which combines the functions of isolating the pump and preventing or controlling reverse flow. The close down period is of the order of twelve seconds. In practice the machines run in the reverse direction for some two or three seconds as the discharge valve is approaching its closed position. This procedure has been found to be advantageous in unwinding from the impeller blades dish cloths and other foreign bodies which appear to lodge on the leading edges near the periphery and which used occasionally to give rise to jamming. The requirement that pumps must be capable of running momentarily in the reverse direction has involved some slight modification to the Michell thrust arrangements and also to the brush gear of the synchronous induction machines. The machines installed in 1953 are of similar design to the originals, the only modification of note being the incorporation of an offset discharge pipe immediately on the top of the pump impeller casings so as to improve access to the pump shaft and impeller and the associated bearings.

There still remain, therefore, in East Hull, further extensive works to be designed and constructed to deal with areas to the west of the Holderness Drain, involving further trunk sewers and major extension of the new pumping station.

West Hull and Haltemprice Joint Scheme

When considering the redesign of the main drainage to the west of the River Hull, it was possible to forecast the ultimate extent of the drainage area with some accuracy. The area is bounded on the east by the River Hull, on the north by agricultural lands of high productivity, and on the west by the Haltemprice Urban District, drainage from which is taken into the trunk sewers. A number of agricultural drains of considerable antiquity, which actually comprise open channels, some of them of major size, traverse the north-western part of the city, where they act purely as carriers. They are a source of inconvenience and danger, and three are to be taken into the trunk sewers of the new scheme. The network of main sewers in the new scheme is illustrated in the map.



Building the brick lining of the crown of one of the tunnels. In the foreground can be seen the completed brick invert lining with safety chains on the right. On the left is the partly constructed entry shaft of a manhole

Calculations based on the conventional Ministry of Health formulæ and an analysis of ten years' rainfall statistics indicated a potential maximum run-off of 63,000 cubic feet per minute and a normal dry weather flow of the order of 3000 cubic feet per minute. Hydraulic considerations indicated that the effluent would be delivered to the pumping station at approximately 28ft below mean tide level. It was, therefore, clear from the inception that no gravity run-off would be possible at any state of the tide or even by limited surcharge of sewers in times of emergency. The reliability and availability of the new pumping station—now known as Humberside pumping station—in consequence assumed the highest importance. Whilst the station was to be designed as a single entity for a maximum throughput of 63,000 cubic feet per minute at any state of the tide, it was clear that this throughput would not be attained for some years and the basis of design eventually adopted for the pumping equipment to be installed in the first stage was 27,000 cubic feet per minute maximum throughput and 2000 cubic feet per minute mean dry weather flow.

The new joint pumping station is designed to deal with the whole of the drainage of that part of the city west of the River Hull in addition to the Haltemprice urban district. Certain trunk sewers, which will serve only the western section of the city and therefore will not form part of the joint scheme, have yet to be constructed. These sewers will form the West Hull Main Drainage Scheme and will, in the main, deal with the drainage of the already developed central areas of the city and the industrial areas immediately to the west of the River Hull. At present, only preliminary design work has been carried out on these projects.

The Old West Hull Station

Before going on to a more detailed description of the new works in the western scheme, it may be of interest to recall briefly the earlier drainage system, which, as we noted above, was built in the last century. In The Engineer of December 27, 1889, we published a fairly full description of the drainage problems at Hull, and especially of the west pumping station—the one replaced by the present scheme—design of which was credited to the borough engineer of that period, Mr. A. E. White, A.M.I.C.E.; the pumps, engines and boilers were supplied by James Watt and Co., Ltd. Needless to say, our article at that time stressed those factors peculiar to the city, outlined at the start of this article, which have made the main drainage problem so difficult. Three compound pumping engines were installed at the old station, each a vertical, inverted, direct-acting machine capable of discharging 10,000 gallons per minute when working at the maximum speed of 20 r.p.m. The maximum lift was 20ft. We noted that the average volume of sewage pumped in dry weather was well within the power of one engine, but on rare occasions, during excessive rains, the volume was considerably greater than the three engines could properly deal with. Normally, the pumps were worked for eight hours on each tide. We also described a "tell-tale" designed by Mr. White, worked by gearing and spindles from the engines, and by floats and platinum wires from the sump and delivery well. "It shows at a glance," our article noted, "the level of the sewage in the sump, which is the same as that in the adjoining sewers, the level of the sewage in the delivery well, which practically corresponds with that of the Humber, and also the head against which the pumps are working. The tell-tale further automatically records the above levels on a roll of paper driven by a clock throughout the day, and indicates the time at which each engine is started and stopped and the number of revolutions worked. To make the instrument more perfect it is intended to attach to it a rain gauge which will automatically record not only the daily rainfall, but also the quantity falling within any given time." This instrument was, in fact, in use until 1937, when it was redesigned. It makes an interesting comparison with the instrumentation for the new station which we describe further on.

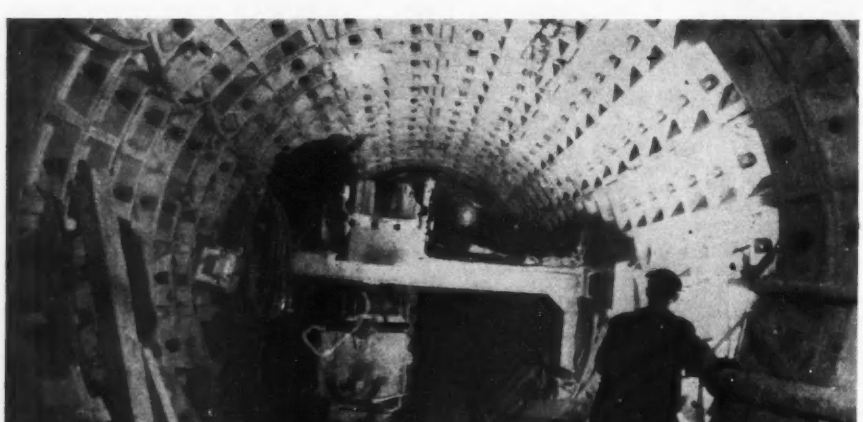
Construction of Main Sewers

The main sewers serving the new pumping station, in themselves, call for a considerable amount of civil engineering work, and the programme for their construction extends over a number of years. The table gives the main data for them, and the sequence of their construction. Most of the work so far, and much of the future programme, involves construction in open cut in steel-sheet-piled trenches, but where the constructional depth is sufficient and ground conditions permit, the tunnelling method is preferred. The two illustrations herewith show typical phases of construction in tunnel. The ground conditions are poor, as already noted. Generally the ground level is at about +12 O.D. and there is about 1ft 6in of made ground, then 10ft of brown clay, 15ft of silt, 1ft 6in of peat, 25ft of boulder clay and 17ft of laminated clay overlying the chalk. Bore-holes are not constant, but the data given above may be considered typical near to the River Humber. Wide variations in depth

of strata occur throughout the area and pockets of sand, gravel and other water-bearing strata are frequently encountered. The sewers are founded at depths of up to about 35ft below ground level.

In a typical example of the trench construction, Larssen No. 2 piles, about 38ft long, form the sides of the trench, and give a penetration of about 8ft below the formation level. The trench is braced with frames of 12in by 12in, 14in by 14in timber or structural steel. The repetitive nature of the work enables the piling and bracing to be used many times. The trench is drained from sumps or by well points. The latter do not, as in normal usage, lower the general water table, but due to the arrangements of sand filters around the well point heads, they give an efficient filtration of the discharge. Experience has shown that when pumping by ordinary methods from a sump, a substantial quantity of silt can also be discharged, resulting in the likelihood of major subsidence near the trench. It should be emphasised that the new sewers are being built in very constricted surroundings, and the trenches often run very close to property or to heavily trafficked roads, where subsidence must be minimised. This cramped nature of the sites of the various sewers has considerably complicated the work, and was, of course, one of the factors of construction for the open cut work, however, is probably nearer 23ft per week.

Three lengths of tunnel construction, totalling 1580 lineal yards in length, have so far been undertaken on the western branch trunk sewer and this work is now complete. There had been no previous experience of tunnelling in the subsoil of the city or its neighbourhood, but the work has proved very successful. The tunnels are normally driven with compressed air at 6 to 10 lb per square inch, but up to 12 lb per square inch pressure has been used. The rates of progress achieved in good ground for driving the tunnel have averaged about 86ft per week (i.e. forty-three lining rings per week). The rate of construction of the in-situ concrete lining has averaged 100ft per week per gang and the rate of brick lining 60ft per week per gang. The plant used for the tunnelling follows along conventional lines for this class of work. The tunnel shield has an external diameter of 10ft 6in and there are electric locomotives hauling the muck skips. Bolted precast concrete segments, 2ft long, arranged with a key section at the top of each ring, which is stepped in alternate rings, are used to line the tunnel. Grouting is carried out soon after construction of each ring of the lining, and an in-situ concrete sewer lining is formed inside the concrete segments, which is in turn lined with engineering bricks. The average rate for constructing the sewer in tunnel was about 30ft per week for all operations involved.



A section of the completed 13ft diameter precast concrete segmental tunnel lining of the Northern Branch trunk sewer. The electrically driven belt conveyor for loading spoil from the face into skips is shown, and in the background can be seen the gear for erecting the segments in the crown of the tunnel

favouring the adoption of tunnelling, wherever practicable. Another was reduction in disturbance, such as to traffic.

Western Branch Trunk Sewer

The permanent construction in trench of the 8ft western branch sewer comprises a mass concrete base where the boulder clay is within reasonable distance (i.e. up to about 3ft) of the sewer formation level, but where the depth of unsound ground below formation is greater, precast or bored concrete piles are employed, with a reinforced concrete beam and slab construction linking them in the trench bottom. A 6in blinding layer of concrete is first placed in the trench, and then the sewer invert is formed in concrete using a steel shutter. A 4½in skin of best engineering brick is afterwards built to line the invert, and the sewer shape completed with an inner arch ring of best engineering brick and an outer arch ring of " seconds " engineering brickwork. Finally, a concrete surround is placed over the brick arch and the trench backfilled, the steel sheet piling being recovered for further use whenever practicable. With a trench about 32ft deep as described here, an average rate of construction of 30ft per week has been achieved on recent work, on sections where an economical length of trench of around 300ft could be maintained. The general average rate

Northern Branch Trunk Sewer

The first section of the Northern Branch sewer is now under construction wholly in tunnel, the method of construction being similar to that just described. The contractor is employing 13ft diameter tunnel shields on each of three faces for driving the tunnel for the 10ft 9in diameter section of the sewer. These three drives will be 2846ft, 2168ft and 1950ft long respectively. Two shorter tunnels will then be driven for the 9ft and 8ft diameter sewers included in this section of the scheme. A pressure of about 10 lb per square inch above atmospheric is necessary. The equipment being employed is again very similar, except that with the larger face and heavier segmental lining units an electrically driven belt conveyor is used to load the spoil into the loco-skip at the face and a hydraulically operated erection gantry is in use for the erection of the precast concrete lining. This equipment is pulled forward by the tunnel shield itself.

The contractor is working three eight-hour shifts daily and is maintaining scheduled progress, the number of rings being erected per shift varying from two to three, according to ground conditions encountered, each ring representing 2ft of tunnel lining. The contractor commenced work on the preparatory surface installations in July, 1955, and the work is expected to take about three years to complete.

The Outfall Sewer

The construction of the 10ft 9in sewer from the new pumping station to the River Humber was carried out in open cut, using steel sheet piling to support the trench, and generally similar construction to that described already for the Western Branch trunk sewer. The work was carried out under very difficult conditions, since the sewer had to be constructed underneath twenty-two sets of railway lines, very close to or under fish filleting sheds, and between two old existing outfall sewers. For this reason tunnel construction was very seriously considered, but was eventually rejected. Much of the steel piling had to be left *in situ* where the sewer passed below railway tracks, and on these lengths the sewer was supported on this sheet piling instead of on precast concrete piles. In other places, where there was boulder clay at formation level, piled support was not required. Construction proceeded very satisfactorily until the excavation approached the river, when " blows " in the trench bottom occurred, making it difficult to get a sound formation on which to construct the sewer. The difficulties were eventually successfully overcome and it became clear that tunnel construction in these circumstances would not have proved suitable. The outfall chamber housing the large timber tidal flap was constructed in the river wall, necessitating the use of a sheet piled cofferdam, within which the river wall was broken through and the outfall chamber incorporated.

Main drainage in Hull is the responsibility of the city engineer and his staff ; the West Hull and Haltemprice Joint Scheme, however, is being directed by joint engineers, Mr. William Morris, M.I.C.E., city engineer of Kingston upon Hull ; and Mr. Robert Heseltine, A.M.I.C.E., engineer and surveyor of Haltemprice U.D.C.

The principal civil engineering contracting firms which constructed the trunk sewers described here are : for the outfall sewer and the Western Branch trunk sewer, the Yorkshire Hennebique Contracting Company, Ltd.; for the first section of the Northern Branch trunk sewer, Mitchell Brothers, Sons and Co., Ltd. A number of contracts for other sections of the Northern Branch trunk sewer have still to be let.

Some further details of the tunnelling work in the Western branch and outfall sewers will be found in the *Journal I.C.E.* of April of this year, when a paper on this subject by Messrs. G. W. Roberts and W. H. Lucas was published.

(To be continued)

Technical Report

Surge Recording at Portobello 132kV Substation (Ref. S/T82). By E. L. White. The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 10s. 6d., postage 5d.—This report relates to two separate investigations of surges carried out in 1950 and 1951 respectively at Portobello 132kV substation. Early in 1950, the surge recorder was transferred there from Meaford (after a report of the failure of a voltage transformer on the Bonnybridge line at Portobello) with the object of searching for a cause of the breakdown in possible abnormal voltage conditions. This investigation involved the recording of surge voltages at the terminals of the bank of voltage transformers after the damaged unit had been replaced. A schedule of switching operations was drawn up to reproduce conditions to which the transformer was known to have been subjected in the last few months prior to failure. No continuous survey of surges under normal service conditions was made on the occasion of this investigation, but in 1951 the surge recorder was again transferred to Portobello for use in connection with a proposed programme of switching tests. These tests were subsequently postponed, but advantage was taken of the availability of the recording equipment to carry out a continuous survey of surges at the terminals of one of the main transformers from April until late summer when the equipment was withdrawn for overhaul. An analysis of the results of these investigations is given in this report.

Institution of Naval Architects Summer Meeting

No. I

BRISTOL was the venue of the summer meeting of the Institution of Naval Architects, which opened on Tuesday, July 9, in the Large Lecture Theatre at the University Engineering Laboratories, University Walk. The Lord Mayor of Bristol, Alderman P. W. Raymond, officially welcomed the members to Bristol and the Vice-Chancellor of the University of Bristol, Sir Philip Morris, was pleased to welcome the Institution within the University. He called attention to the building in which the meeting was being held, and suggested that it was worth looking at since it was an interesting example of applied architecture and applied civil engineering, the retaining walls being of particular interest.

Following the official speeches of welcome, to which the president, Lord Runciman, replied, two papers were presented and discussed. In the afternoon the members went by coach to Filton to visit the Bristol Aeroplane Company, Ltd., and toured the hangars to see " Britannia " airliners in various stages of construction. The opportunity was also afforded to the members to witness the water testing of the fuselage and the programmed stressing of the wings under electronic control.

On Wednesday morning, further papers were read, while in the afternoon some of the delegates made a detailed tour of the University Engineering Laboratories and were able to see several of the research investigations currently in progress. Other members and their ladies visited the factory of W. D. and H. O. Wills, at Bedminster, and witnessed the various processes involved in the manufacture of tobacco. In the evening the members were the guests of Sir Philip Morris at the sherry party held in the Reception Room at the University.

There was no technical session on Thursday morning, but two visits were arranged. Some members journeyed to the chocolate factory of J. S. Fry and Sons, Ltd., at Somerdale, while the others toured the Avonmouth Docks to see some of the storage and transit sheds and the cold storage arrangements. Both parties were invited to luncheon at the Ashton Court Country Club by the Port of Bristol Authority, and later the members and their ladies were received by the Lord Mayor at the Mansion House, Clifton Down and entertained to tea.

During the course of the summer meeting five papers were presented, and the first technical session was held on Tuesday morning, July 9, with Viscount Runciman in the chair, when the following paper was read.

MERCHANT SHIP DESIGN : SOME ÆSTHETIC CONSIDERATIONS

By Laurence Dunn

Synopsis

This paper deals with the exterior shape of ships and discusses the forms of bows and sterns, the treatment of masts and derrick posts, the trends in funnel shapes and the outline design of superstructures and deck erections. Attention is drawn to the principles of composition and constructive suggestions are put forward with a view to improving the outward appearance of British-built ships.

In presenting the paper Mr. Dunn showed a large number of slides of a wide variety of ships, which served to illustrate the points made.

Discussion

Professor E. V. Telfer : I am always in favour of criticism of the work of naval architects, and we should try to meet that criticism by stating what naval architects try to do scientifically in the production of a ship's form. It is sometimes thought that you give to a ship a sheer, a stem and a stern ; but you simply cannot do that. Once a ship has a shape the shape dominates the whole of the other features of the ship. Correct water line shape automatically produces your stem outline, so that we have not the licence to produce the stem shape we may imagine if we adopt the right principles in the design of a ship. The same holds good in respect of the stern.

In regard to sheer, you may want a parabolic sheer, but when you look at the ship from about 45 deg., instead of the sheer line being constantly upwards, it appears to drop at the stem head. To avoid that you must take a section through the ship at 45 deg. and see how to continue the sheer upwards in a continuous manner and to avoid that falling away.

The lettering of the ship's name should be parallel to the sheer ; the letters can be heavy, but there should be very considerable space between them, because names have to be seen from a distance.

Ir. J. H. Krietemeijer : It is difficult to discuss the æsthetics of ships, for this depends so much upon the individual taste of the observer ; further, one can judge only from the actual ships and not from pictures or drawings. Taking the illustrations in the paper of superstructures (Figs. 7, 8 and 9), it is very difficult to decide whether or not an improvement has been effected, the only important difference being the inclined stanchions. If the funnel, ventilation cowls, bulwark stanchions and davits remain perpendicular, what is the use of inclining the stanchions ? If this is done to give an impression of speed, I do not think this will mean much in the case of a ship having a speed of 15 or 16 knots.

Stemplates are very difficult to shape, and I suggest that the so-called German current style (Fig. 3 (*E*)) be adopted and a conical stemplate be applied. The water lines can fit to this conical stemplate. For the stern, the shape in Fig. 4 (*D*) is to be preferred, for it involves the double curved plates.

The æsthetics of a ship depend largely also upon the sheer, but even the sheerless ship, e.g. the modern tanker with the curved sheerstrake (Scandinavian type), can be æsthetically designed.

The bow decorations originated from the clippers and other sailing vessels. The lines were beautiful and encouraged shipbuilders and owners to end this shape in the form of a human body bearing the bowsprit on its back. On the modern widely curved stems of cargo ships these figureheads are ugly, and we ought to dispense with them.

The names carried on the bows of ships are sometimes difficult to read. Why spoil the bow with large characters when a simple board or even lighted characters of larger size can be placed on the superstructure ?

Mr. A. J. Merrington : To me that the ultimate test must be that a ship can do her job well ; in other words, it must be functional and not merely prettiness.

In Fig. 3 the author gives a series of bow shapes. From considerable experience of the North Atlantic winter I feel most strongly that good sheer, good freeboard forward and a good raking stem of something like 25 deg. are essential for good sea-keeping qualities. The author has not spoken of the current fashion of large rounded contour effects, particularly above the water line, versus the knife-edge. In the new frigates, where these rounded contour plates are fitted, they have a practical value in that they enable us to fit recessed anchors by getting a greater width above the water line. Incidentally, they provide more buoyancy and a better run of the seas around the ship, instead of the seas feathering off and causing spray in a seaway. I think that the form of stem with this large radius fulfils the tests of appearance and performance. As a naval architect I should like to get rid of funnels altogether, and I suppose, with nuclear propulsion, that will come.

There is a very considerable movement afoot to-day to try to reconcile the humanities with the applied sciences. We have a correct shipbuilding tradition in this country and it seems essential that art and shipbuilding should not be allowed to drift apart.

Mr. J. Burton Davies : It is not enough that a ship should be technically efficient ; everything about her should be of the best, since in many parts of the world people judge a country by the appearance of ships flying that country's flag. Æsthetic considerations need not conflict with structural requirements, and often what is desirable from the structural point of view will also improve the appearance. Shipbuilders have learned that in dealing with welded ships one must avoid " hard points," and this applies just as much to the ends of superstructures as to the ends of stringers. Thus at the end of a bridge erection a design such as that in Fig. 1 (*D*) in the paper, is both good looking and good structurally. Similar remarks apply to the suggested alterations to the break in the deck of the ship shown in Fig. 9.

For the large bulk carrier with all erections aft, Mr. Dunn suggests the provision of a secondary navigating position in a crow's nest on a samson post forward. It may be of interest to mention that this has already been done on a large Scandinavian tanker, and I believe that no navigational difficulties have been experienced.

Mr. K. C. Barnaby : It was the exterior decoration of the old-time sailing ship that really mattered, figureheads, elaborate carving and gilding, decorative lanterns, and so on. To-day we have reversed all this and have let the interior decorator do almost as he pleases. The naval architect has been persuaded to fit heavy and expensive girdering in order to avoid over-close pillaring, and has had to adjust his web frames and window spacing to suit a decorative " scheme." It does seem a little illogical to devote a vast amount of attention to the interior and neglect the outside appearance.

Mr. Dunn pleads with us to pay a little more care and attention to the exterior details that can make or mar the general appearance, and little or no extra expense is involved in carrying out many of his suggestions, such as more pleasing curves to bow and stern, &c. Here symmetry is specially important, since the whole profile is visible at once, so that the designer must not chop and change his style. Surely it is the passenger liner that is in the greatest need of an attractive appearance, for the ideal of some owners seems to be the nearest possible approach to a block of flats, containing communal recreation and feeding facilities.

Mr. A. Silverleaf : The critical point Mr. Dunn has emphasised is that the outboard appearance must have a balance point and it

must be uncluttered, and I suggest that the major fault in most of our ships, particularly British, is the lack of balance point, and they are far too cluttered. The details of bow shape, stern contours, and so on, are incidental, I suggest, to the overall conception.

In many instances one can fulfil the functional requirement in more than one way, the final decision, however, resting upon individual opinion and choice. A major problem is that the people who make the decision are not qualified to do so. People like Mr. Dunn, I suggest, are far more competent to decide what is pleasing and what is not pleasing. Most of us are familiar with the ferry *Royal Iris*. When we designed it we were given a free hand to produce something which was in fact a water bus. When it went into service there was criticism of its appearance because it was a mess. The reason for this was that we were told that the vessel would be exempt from carrying lifeboats, but at the last moment the Ministry of Transport said that there must be six lifeboats. What chance has a naval architect under such circumstances ?

In another type of vessel, particularly patrol cruisers serving in northern waters, we had achieved what we believed to be a balanced structure. Here we had difficulty in regard to the requirement of carrying signal lamps. In many cases the naval architect reads the rules and finds that he must have lights at a certain distance apart ; he deals with the requirement in the simplest and most practical way, and that leads to the results which Mr. Dunn criticises.

Thirdly, I mention the cross-Channel ship and quote a particular feature to illustrate the way in which a practical constructional point can be incorporated in a ship's design initially without much success, but eventually with considerable success. I am speaking of the knuckle stern, which was developed to give more deck space. The original vessels incorporating this stern were rather ugly, but over the last fifteen years there has been successive gentle easing and modification.

Since it is the man who can see what will happen ten to fifteen years hence who should settle what contours should be like, I suggest that no man more than thirty-five years old should be allowed to make the final decision.

The President : I agree that the appearance of a ship has got to be related to the function which she has to perform and it follows that you should not have this elaborate streamlining in vessels where it is quite unnecessary. The point has been made that we ought not to have a figurehead on a modern ship. The original reason for making the soft stem was that when a ship bumped into a quay wall repairs would cost less. I do not feel that the figurehead is worth while.

A matter which interests me concerning the paper and the discussion is how little has been said about funnels ; I suppose the old funnel had to be long and thin, the modern funnel does not need height to the same extent, and I suppose that in a diesel ship its only function is to discharge the exhaust where it can be out of the way. People insist on using the funnel as an architectural feature. But the problem of disposing of what comes out of the funnel is enormously increased by the increasing speed of ships, and I should like to see a turn away from short funnels and experiments made on combining the funnel and mast, giving a longish thin tube, ensuring that exhaust gases come out a very long way from the deck.

It is advantageous to the shipowner that his ship shall be pleasing to the beholder ; that is part of the functional consideration which should be borne in mind. The first ship that my grandfather commanded, which was built for the China trade, had bulwarks made of polished mahogany, and I am told that the Mandarins' opinion of her was such as to prove highly profitable.

I am not prepared to subscribe to the view that all decisions should be left to people who have not yet reached half the normal span of man's life. We build a ship to last twenty or twenty-five years, and what people admire at the end of its life they will admire at the beginning. I am perfectly clear that the ultimate decision on matters connected with the construction of a ship are the owners, they have to pay for it, and if they make a bad decision they will pay a great deal more.

(To be continued)

Design Problems of Large Rockets

By K. J. BOSSART

Yesterday, opening day of the High Altitude and Satellite Rocket Symposium organised by the College of Aeronautics, the Royal Aeronautical Society, and the British Interplanetary Society, a paper including a study of geometrically similar rockets of different sizes was given. It appeared that a rocket of 50 tons launching weight might have the minimum proportion of dead weight.

SAD but true, is the fact that possibly the biggest problem we are confronted with is largely unrelated to physical characteristics. Instead, it stems from human failing. I am referring to the inability of even the most competent engineering groups to come up with a design that will be trouble-free from the start. Those men who had field experience with experimental missiles have had to struggle with sticky valves, stray voltages, crosstalk, pressure surges, resonant vibration, contamination, and so on. To them, design problems yielding to numerical analysis are child's play in comparison.

These difficulties are a direct function of the complexity of the device. They are present also in aeroplanes, motor-cars or ships. The main difference is that in missiles, engineering hindsight cannot be acquired from shakedown cruises.

Not only does every flight test mean the loss of a missile, but monitoring every possible malfunction in flight is an impossibility. The only substitute for a shakedown is captive and laboratory testing. It is a poor substitute, since flight environment cannot always be properly simulated.

In this respect, the large missile is at an even more severe handicap than the smaller one, since due to the expense involved, it will be flown in lesser numbers. The " debugging " effort, therefore, must be more intense. A more extensive ground-based testing programme is justified. In flight a more elaborate telemetry system should be provided to detect malfunction.

There is still another reason why the large vehicles may prove more troublesome : they are probably designed to a greater degree of refinement and, therefore, less tolerant to small errors.

Here now, in my opinion, we have touched upon the essential difference between large and small missiles from the standpoint of the designer.

The difficulties peculiar to the large missile are those that are brought about by refinement in design. In smaller vehicles, such refinement is often impractical for manufacturing reasons. In the larger category we cannot afford to overlook this if we wish to keep down size and cost.

The problems that keep the large missile designer lying awake nights all stem from one fundamental requirement—that his big missile be kept from growing still bigger.

(The author here made his analysis of airframe weight, showing a minimum dead weight/total weight ratio of 0·06 at and just above 50 tons launching weight.)

As we emerge into the era of 50-ton weights and heavier, performance should greatly exceed that of the past decade. With further missile growth, performance will again become more costly.

What can the designer do to minimise this cost ? First of all, he should select the best flight trajectory to accomplish a given mission.

This task generally consists of a tedious process of optimisation through compromise. Let us suppose, for instance, that we wish to throw a vehicle into a satellite orbit. The laws of kinematics show us that the propulsion efficiency of a rocket increases with speed. We should, therefore, adopt a flight path that permits the fastest possible increase of velocity. Obviously, this is a horizontal path. The missile should be made to graze the surface of the earth, accelerating all the time until its accumulated kinetic energy is sufficient to coast along a Kepler ellipse, to the required satellite altitude—there to receive its last increment of impulse.

This would be fine if we launched from a planet devoid of atmosphere. When launching from the earth, such an approach would not only waste energy in the form of drag, but the heat generated by air friction would burn the missile to a cinder. From these considerations, it appears that the best flight path is one that emerges from the denser layers of the atmosphere as soon as possible, namely, a vertical flight path.

The true optimum flight path is, of course, a compromise between these two extremes. Where this best compromise lies depends on a number of things.

It depends on the size of the missile. The larger missile having a thicker skin will be able to cope with higher rates of aerodynamic heating and will, therefore, be able to follow a flatter trajectory.

By the same token, it depends on the materials we choose to build the missile from. Both specific heat of the material and the rate of strength deterioration with temperature have to be considered.

Another influence is the magnitude of thrust at take-off, or, more accurately, the thrust-to-weight ratio of the missile. If the launching acceleration is high, the missile will dwell in the atmosphere for a shorter time ; therefore, a flatter trajectory is permissible.

A further complication is staging. In the present state of the art, a satellite missile must of necessity be staged. What is the best proportion between the various stages ? What thrust-to-weight ratio should each stage have ?

All these possible design alternatives are mutually related. A change in one is likely to affect all the others. The best combination can only be found by a process of feedback and reiteration.

Having established the optimum flight path, how shall dead weight be reduced ? The designer should be obsessed by the need to eliminate every bit of unnecessary weight by giving utmost attention to detail. He should minimise the amount of trapped propellants. He should apply such tricks of the trade as having one part accomplish more than one function.

Materials of the highest strength-weight ratio must obviously be used. In the larger missiles the job of the structures engineer becomes harder. No longer can he hide his sins behind minimum gauge material. No longer can he shrug off transient loads, mild eccentricities or stress raisers.

The one all-pervading influence on the design of a missile is the choice of the propulsion system. What should the propellants be ? What should be the thrust level ? Shall we prescribe single or multiple motors ?

I shall dismiss solid propellants with the state-

ment that, in my opinion, they will never be competitive in very large missiles. Although astonishing progress has been made in this field, I believe that the handicaps of high cost, unavoidable combustion chamber weight and handling difficulties will preclude the solids from the large missiles.*

Among the liquid propellants, the cost advantage of the oxygen-hydrocarbon combination is very difficult to overcome. Unless the cost of the high specific impulse propellants comes down several times from what it is to-day, no economy will result from their use in the first stage of a missile. Only the size will be reduced, not the cost. The so-called super-propellants should, therefore, be reserved for second and third stages of multi-stage vehicles. In this case, the increased cost of the propellant in the upper stages will be more than compensated by the reduction in size and cost of the first stage.

The question of single versus multiple engines will again be resolved by considerations of economy. The unit weight of large rocket motors goes up with size. Furthermore, the nozzle length of a single motor is longer than that of a cluster of equal thrust and, therefore, the weight of the fairing that encloses the single engine is also larger. Both of these effects favour the multiple motor arrangement. On the other hand, the single engine is less complex and, therefore, more reliable. In the final analysis, it is the development cost of the large engines that will be the deciding factor. Very large missiles—let us say of the 1000-ton class—will probably not be built in quantity. Development cost then will be a large part of the unit cost, and it will be cheaper to utilise clusters of existing engines than to create a bigger one.†

Still another important question the missile designer has to ask himself is—how much thrust should the missile have ? Assuming that we are talking about vertically launched vehicles, the thrust obviously has to be larger than the take-off weight. It turns out that for optimum performance, it should not be very much larger. The trend for thrust-to-weight ratios in modern missiles is downward. Initial accelerations of less than $1 \cdot 5\ g$ are the rule.

The theoretical optimum depends on the mass ratio of the missile and on its structural efficiency. It could be as low as $1 \cdot 2\ g$. Calling for this low a thrust ratio in the preliminary design phase is fraught with danger, since unanticipated weight growth might well jeopardise the final product beyond repair.

Before we leave the subject of propulsion, the matter of residual propellants should be mentioned. The weight of unusable propellant left over at burn-out could have been payload weight instead. Barring plain carelessness in design there are three sources of residuals :

(1) Propellant pumps requiring too high an inlet pressure are unacceptable, as they will leave much liquid ahead of them at burn-out.

(2) Rotation of the propellants in the tanks will cause vortexing at the outlets. The result will be entrainment of air before the tanks are completely empty. To avoid this, suitable baffling should be provided.

(3) If the tanks are not filled to the correct levels, or if the motor mixture ratio deviates from the required value, one of the two propellants will run out before the other. The remaining propellant is, of course, useless. Since the mixture ratio varies during flight with temperature and thrust acceleration, it is extremely difficult to ensure that both tanks will be empty simultaneously. Reliable devices which correct the mixture ratio in flight in order to achieve this requirement present a challenge to the gadgeteer.

Let us examine next how the design of flight controls is affected by missile size. Intuitively, it can be seen that the larger a missile the more sluggish it will be. To execute a given command will require more time. Or if it is desired to execute a command in a given time, the required control forces will be larger.

Fortunately, in the type of vehicles we are talking about, rapid change of direction is not a requirement. In that case, the magnitude of the control forces and the rapidity with which they can be brought to bear is determined by their ability to counteract atmospheric disturbances. This is particularly true in the case of aerodynamically unstable vehicles, since a control force that is too small or too slow can let the missile deviate to attitudes which are beyond recovery. We have recourse again to the scaling laws : and find that the jet deflection required to counteract a given angle of attack varies as $1/L$, and that the undamped natural frequency of the system varies as $1/L$. So for equal dynamic behaviour not only can the jet deflection be smaller for larger missiles, but the speed at which it deflects can be less. Slower deflection speeds not only reduce the actuating forces but also permit better linearity in the system. It appears, then, that from the standpoint of the flight control engineer, bigness of the missile is a help rather than a hindrance.

Structural refinement of large missiles, however, brings about further control problems. Weight saving cannot be done without loss of rigidity. Unfortunately, higher strength alloys do not have an improved Young's modulus. Bending frequencies, therefore, go down and begin to approach the servo frequency of the missile. Gyros cannot distinguish between angles or angular rates due to missile attitude and those due to missile bending deformation. The rate gyros are particularly bothersome.

This problem requires thorough analysis but can generally be solved by judiciously locating the gyros and by designing the control servos in such a way that they will filter out the undesirable frequencies. If this cannot be done, special rejection filters may have to be resorted to.

There is still another phenomenon affecting missile control—namely, propellant sloshing.

The effect of a liquid sloshing in a tank can be rigorously simulated by a free swinging pendulum located approximately at the surface of the liquid.

When the control system of the missile senses an attitude error, it can only correct it by applying a lateral force. A lateral acceleration of the missile ensues. While in the atmosphere, moreover, this lateral acceleration is greatly magnified by the lift forces exerted on the missile. Lateral motion will create a side force at the fulcrum of the pendulum inducing a moment about the c.g. of the missile. When the frequency of oscillation of the pendulum approaches that of the control servo, coupling will result. The system tends toward instability when the pendulum is located forward of the c.g.

The pendulum frequency is proportional to the square root of the longitudinal acceleration and during the flight of a high mass ratio missile will cover an octave or so. What is worse, this octave can be expected to straddle the servo control frequency (i.e. the frequency of the airframe-plus-control servo loop).

Now why should this problem become important in large missiles when it has been generally ignored in small ones ? The reason is the magnitude of the forces involved.

The mass of the equivalent pendulum turns out to be equal to that of a depth of liquid of $0 \cdot 2$ tank diameters. Turning to the scaling laws again, we see that the inertia forces involved are proportional to L^3. We know that aerodynamic and control forces only vary as L^2. The magnitude of the problem, therefore, increases in proportion to L.

Throughout this study, I have based my conclusions on comparisons between vehicles of geometrically similar shape. It may be argued that this was a fortuitous assumption and that, therefore, my conclusions are invalid. It is true that when optimising drag against weight, the results show that smaller missiles would be slender and larger ones stubby.

I will grant that smaller missiles will, as a rule, be thinner than the slenderness ratio I have assumed. Admittedly my weight curves are not much good in the region of $L<1$. This is not the region we are interested in, anyway.

As for larger masses I contend that my assumption of geometric similarity is justified. It is justified by the presence of the sloshing problem. Sloshing forces go up as the cube of tank diameter. Therefore, trading length for diameter will be dangerous in large missiles.

In conclusion we may ask ourselves : Are there any design problems that will become insurmountable when the size of missiles continues to grow ? Or : How large will "large" missiles ultimately be ?

The answer to the first question is no. To be more specific, no insoluble problems will arise before missile size reaches a limit set by other factors than mere engineering design.

To be sure, as missile size increases, the dead weight ratio gets worse. Conceivably, when the missile gets large enough, the dead weight will increase at such a rate that further growth would neither increase the payload nor the burn-out velocity. Fortunately, such a state of affairs would only occur when the missile reached a tonnage well beyond that of the "Queen Mary."

What factors, then, will set a limit to the ultimate size of missiles ? As I see it, two.

First, the limit will be set in relation to the size of man himself and the size of his tools and environment, just as the size of ocean going vessels was limited by the depth of the harbours and the dimensions of the canals.

Second—and more probably—the limit will be set by considerations of operating economy, just as it was for other means of transportation. When it becomes cheaper to accomplish a given mission with two smaller missiles rather than with one big one, the limit will have been reached. The degradation of the dead weight ratio with increasing size will hasten the arrival of the limiting size.

* On the same day, Professor A. D. Baxter demonstrated that the thrust/weight ratio with a solid propellant was inferior except for burning times less than twenty seconds and very high accelerations.

† Professor Baxter also considered parallel operation, showing that its advantage in a gravitational field was countered by more drag and, possibly, weight.

Titanium Display

THE increasing production of titanium has enabled Imperial Chemical Industries, Ltd., to develop applications where its excellent corrosion resistance properties are of especial value. This applies particularly to the oil industry and for chemical and allied plant, and we were able to visit a display, held at Imperial Chemical House, Millbank, London, based on this year's exhibit at the British Industries Fair, which demonstrated the noteworthy characteristics of titanium, namely, the high strength to weight ratio coupled with good mechanical properties even at elevated temperatures ; high resistance to erosion, to most forms of chemical attack and to stress corrosion cracking.

Mild steel vessel, 4ft long by 4ft diameter, lined with titanium sheet, and (left) lined domed end

In the display were several examples of valves and pumps of which parts were made of titanium. There were cast iron valves lined with titanium and a high-pressure needle valve for handling a variety of corrosive gases. Examples of pump impellers gave evidence of great corrosion resistance compared with other materials. Other exhibits included titanium mesh, expanded metal mesh, lens rings, orifice plates, and a mild steel vessel lined with titanium sheet which had been attached to the mild steel body by a special spot welding technique. The corrosion resistance makes it possible to use certain bleaching chemicals for the first time, for since there are no corrosive products there is no contamination.

LITERATURE

Book Reviews

Atomic Quest. By ARTHUR HOLLY COMPTON. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 30s.

THIS is a remarkable book and quite fascinating to read. Though autobiographical in form, it is full of technical information derived from the author's very varied experiences during the 1939-45 war, and the whole blended into a single story of which a most striking characteristic is the marked strain of altruism that runs through the whole. Colonel Compton as an eminent American physicist, and Nobel prize winner, had the important task during the years between 1941 and 1945 of acting as liaison officer between a group of the leading nuclear scientists in U.S.A. and the American Army Administration. Within this critical period was seen the attainment, for the first time in the world, of a self-sustaining nuclear-chain-reaction, which Fermi's research team brought about in a quiet court in one of the buildings in the University of Chicago on December 2, 1942, with, or without, the knowledge and assent of the University's President! This pioneer step, taken on a date which will be long remembered, led to developments on a rapidly increasing scale and the bold forecast was made that an atom bomb might be ready as soon as the spring of 1945. What might be happening in other countries, especially in Germany, was then in considerable doubt; but it seems sure that the prospect of German rivalry had a decided bearing on the covering approval given (in December, 1941) by President Roosevelt on the very day before the Japanese attacked Pearl Harbour. Britain and the U.S. thus became Allies in the war, as their physicists had been in sharing the earlier scientific work involved—though the degree of co-operation was not a little affected by some nervous reaction on the part of American Congress at the risk of the later secret work becoming known in other lands, Allied or otherwise. It was, however, agreed between Roosevelt, Churchill and Mackenzie King at a Quebec Conference in 1943 that the common war effort of the Western Powers in this field should be centred in North America. Actually, a British scientific team had been in America since January of that year. Colonel Compton writes with intimate knowledge of all these matters, as well as of the vital policy decision which had to follow as to the targets to be chosen whenever the first bombs were ready for warlike use. On some of these matters little information has been published hitherto, and many readers will learn much that is new to them. Colonel Compton writes not only with knowledge and sympathy, but shows himself to be ready to exercise his own moral judgment, which he commonly expresses with great earnestness and an unusual measure of frankness.

The whole effort in America was carried out with characteristic energy: thus, three important schemes were put in hand simultaneously—the preparation by an elaborate diffusion process of uranium 235, its preparation by an alternative electromagnetic method, and the large-scale production of plutonium (under the author's personal supervision). These three schemes occupied some two and a half years, and had to include the choice of a "moderator" to aid the new process of fission in the nuclear reactor, calling for an early assessment of the respective merits of carbon, in the form of graphite, and heavy water. For the design and construction of actual bombs a laboratory, at Los Alamos, was specially prepared; it began work in the year 1942 and the first test bomb was exploded in 1945.

Once an atom bomb had been produced and had successfully passed its "test explosion," (in New Mexico on July 18, 1945), the question arose as to what would be the right way to use such a weapon to bring to an end the struggle with Japan? Some of those in authority advised an experimental demonstration on an uninhabited island in the Pacific Ocean with Japanese observers present; others preferred its immediate military use over Japan itself. A high-level committee meeting in May, 1945, to assist the Government to decide this question, recommended some form of direct military action. Two bombs were immediately made ready and both of them were used—lest, as Colonel Compton puts it, the enemy should imagine that the U.S. had but a single atom bomb available. The author describes graphically the difficulty felt even then by the Japanese at giving up the struggle, despite the bold endeavour of their Emperor to persuade them along this course, with his assurance that the invention of such an unprecedented weapon made it possible for them "to resign with honour" from a war which could only produce further disaster.

In 1945 the atomic bomb was generally accepted as the "super-bomb" in future military equipment. Professor P. M. S. Blackett in his "Lees Knowles" lectures at Cambridge in the spring of 1956, estimated that America had then available some 30,000 nuclear bombs, whether of large size for strategic bombing, or of medium size for tactical use, as well as some for anti-submarine purposes (Britain's own first atom bomb was tested in Australia in 1952, some seven years after the explosion of the first American one). When the war ended Colonel Compton turned at once to other work, and although he had helped to prepare a programme for future American investigation into the use of nuclear energy for civil purposes, he left it to others to carry out that side of the Atomic Quest and little is said in his book on this side of the subject.

To engineers it is hardly surprising that the lines of development for civil reactors planned for Britain and the U.S.A. should now differ as much as they do. This is less because of any divergent lines of thought, but because Britain contains so little coal and the U.S.A., in comparison, so much. Britain has to select a course likely to provide rapidly an alternative source of power, whereas America can devote time to the assessment of the respective efficiency of the many civil reactor designs proposed by her industrialists. Thus, the simple gas-cooled, graphite-moderated reactor known as the Calder Hall type, has been adopted for early and rapid production in Britain. Pioneer work continues also with model reactors at Harwell and other establishments, besides the important venture into a fast breeder, liquid-metal cooled, reactor in the establishment at Dounreay, in the North of Scotland.

It would have been interesting if Colonel Compton had been able to add to his story some account of what America is prepared to do in educating its young engineers for work in the nuclear power field. In Britain the first college to establish a Chair of Nuclear Power was the Imperial College at South Kensington, and its first holder, Professor Kay, initiates, in this coming October, a year's full-time post-graduate course in nuclear power. One can certainly rely on a steady demand for engineers trained to work in this field; senior technical executives can attend short refresher courses at the Reactor Schools at Harwell.

The author modestly summarises in these words his share in the "Atomic Quest": "Scientists at work in many nations had prepared the stage for these events. Fifteen thousand men and women took part in the war research that showed the way. More than half a million workmen were actively engaged in making the first atomic weapons." Thus was brought to its dramatic close the war with Japan, and the world presented with a new and vast source of much-needed mechanical energy to provide for its civil requirements in the busy era that lies ahead.

His Royal Highness the Duke of Edinburgh's Study Conference on the Human Problems of Industrial Communities within the Commonwealth and Empire, 1956: Volume I, Report and Proceedings; Volume II, Background Papers, Appendices and Index. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 42s. (two volumes).

VOLUME I tells the story of the conference, with the opening addresses; gives the eleven papers read at plenary sessions, twenty-one reports from the study groups into which the conference was divided, the Archbishop of Canterbury's sermon and the summing-up by Sir Philip Morris. Volume II gives twenty-four background papers, sent out in advance, but not read at the conference, and fifteen appendices, largely on conference organisation and directories of committees, members and advisory panels.

Collections of papers, even by the same author, seldom make easy reading. When they are by different authors, however distinguished, interest aroused by the variety of style soon gives way to a feeling of frustration that no single author has had sufficient space to work out his theme completely. Each of the background papers in Volume II which range from "A Note on the Adolescent Girl in Britain" to "The Changing Quality of Political Life" and "Notes on the Impact of Industrialisation and Science on Morality and Religion," is in itself good. But each can be no more than an introduction to an immense subject deserving at least one book to itself. To regard the papers of Volume II as contributions to a para-technical journal is to do them less than justice; to read them consecutively as a book is, in spite of the excellent grouping, wearisome. The papers of Volume I were written to be spoken to plenary sessions of three hundred conference members; they were not written primarily to be read. As reading they inevitably suffer, as do all records of conference proceedings. Statements tend to appear more dogmatic than if they had been intended for reading, arguments over-simplified, and jokes flat and,

for the most part, superfluous. On a public platform, a well-timed witticism can lighten an otherwise heavy speech, in a book it frequently interferes with concentration on a serious argument.

Thus, the two volumes make dull and repetitious reading, but it would be clearly inappropriate to criticise them as books. It is tempting, therefore, to review not the books but the conference itself as revealed through them, but it is doubtful if anybody who was not present at the conference can make adequate comments on it. Most conference organisers, and this applies to the Industrial Welfare Society on whose initiative the conference was called, would agree that the most valuable part of any conference takes place outside the plenary sessions ; and this is precisely the part of the conference most difficult to record. The reporting back of the study groups (ninety out of the 677 pages) does something to fill the gap, and the extracts of the closing speeches give something of the " climate " engendered by the end of the conference. This was a great and imaginative experiment ; the Duke of Edinburgh emerged strikingly as the leader of the conference in his own personal right. The conference organisation was superb, as is evidenced by the tremendous amount that was accomplished in so short a time. That the conference will live on in the minds of those who were there, and will influence their future behaviour there can be no doubt. Dr. Kelsall, concluding his report for Group H, said : " . . . the study of these problems together in our groupings has brought out the underlying value of this conference—its deep effect on all of us."

It may be asking for the impossible to wish that the report of the proceedings had included more study of the conference as a conference. Mr. Mash, reporting for Group J on " Adaptation to Change," said : " . . . one or two of us had the striking thought that it (the group task) would be better done if we had the job of following other groups around to see how they reacted to change." Such a report would of necessity take longer to produce than the present two volumes, but it would be a very worthwhile contribution to the present scanty knowledge of this comparatively untested method of communication. Perhaps a third volume may still emerge when the organisers have had time to reflect on the results of their work.

This reflection is encouraged by the reports from the groups which studied " Satisfactions at Work." All of them reported pay as the most important satisfaction. This finding is at variance with most other published studies, and it is not uninteresting that topics " which are subject to negotiation including wage rates," were outside the terms of reference of the conference. Sir Philip Morris in his summing-up, referring to the work put in by the conference secretarial staff, who, by working all night, produced a complete record of the reporting back sessions in time for the next day's summing-up at 10 a.m., said : " There is perhaps no satisfaction at work like giving satisfaction by your work." He recalls that at 2 a.m., when he visited the team stencilling, duplicating and binding, " I found them still going strong ; I found that after the initial difficulties and anxieties of settling down to work through the night, they had achieved that exceedingly happy state when nothing could matter except getting the job done in time." Perhaps many groups travelled too far to see what was in their midst.

The University Press has done a first-class job of printing and production and the two volumes as they now stand will serve those who attended or had anything to do with the conference, as an excellent reference and reminder. To others, the books will have a limited appeal, marking an event rather than describing it.

Machine Drawing. By DEANE LENT. Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, London, W.1. Price 63s.

IN these days of intense engineering development in so many fields, and an acute shortage of good designers and design-draughtsmen, any book intended to assist students, improvers, and men already in practice to master this craft is worthy of the closest attention. The present author is Assistant Professor of Engineering Drawing, at the Massachusetts Institute of Technology, and he treats his subject in three phases : Design, Detail, and Assembly. The first phase is dealt with very briefly, in no more than twenty-four pages, whereas over 300 are devoted to the detail stage. It is true that his subject is " drawing " rather than " design " ; but in these days one fancies most chief draughtsmen are experiencing far more acutely the lack of men who can originate and thrash out design, rather than lack of detailing capacity. Nevertheless there is far more to detailing than the mere representation of the job on paper, and although Mr. Lent devotes a great deal of attention to the technique of drawing we are glad to note his practical approach to more vital matters, such as the control of manufacturing accuracy, with which is associated the difficult task of deciding methods of dimensioning and tolerances, and his useful description, as it affects drawing office men, of manufacturing processes.

In his treatment of the third phase of his subject, namely, Assembly, the author discusses methods of checking. He instances three, and in view of the reliance that is now placed upon the detail drawing in modern production methods, as referred to in a leading article in THE ENGINEER : " The Role of the Drawing Office," some more detailed reference to this part of Mr. Lent's book will be appropriate. His three examples of methods of checking are : (1) inspection ; (2) construction of a sample machine ; (3) making a check assembly drawing. It is difficult to understand his contention that in method (1), " a great many calculations are required in checking the dimensions and errors are almost unavoidable." It is certainly true that many calculations are involved, but it would evidently astonish the author to know that many British designs go straight into production from this method of checking, and experience little or nothing in the way of teething troubles. Of course in the case of projects involving points of novelty in principle and manufacture, the manufacture of some form of prototype is essential ; but in many instances to-day production is so urgently required that detail drawings are issued to the shops after an " inspection " check, while as an additional safeguard, a check assembly drawing is made on the lines described by the author immediately afterwards, so that any possible errors made are discovered before tooling up has gone too far.

The book is primarily intended for students, but to-day one finds " students " of all ages, and all these may derive benefit from a study of the many specific problems that the author has included at the end of his book. If one might make a major criticism it is that the author has omitted any reference at all to the choice of materials as they affect the detail of engineering components. Presumably he has taken the view that choice of material is outside the province of those for whom his book is intended, though in the great majority of drawing offices it is inseparable from the ordinary run of day-to-day work.

Nuclear Power Year Book, 1957-8. Rowse Muir Publications, Ltd., 3, Percy Street, London, W.1. Price 42s.

WHAT is claimed to be " the first and only year book and buyer's guide to the British nuclear industry " is a bold attempt to scan a very broad field. Lord Mills, the Minister of Power, draws the moral in his foreword by greeting the appearance of the book as " a sign that atomic energy has, in the space of a few years, passed from the stage of offering merely exciting prospects to one of practical achievement." The truth of this is plainly indicated by the proportion of pages carrying commercial information. Company addresses, the buyer's guide, and a list of trade names take up between them some 200 out of the 500 pages. In contrast with this there are only eighteen pages in the " Technical Data " section ; this is misleading, however, since additional technical information appears in the " Isotopes " section and the reviews. The many articles include among their subjects : isotopes, instrumentation, mining, zirconium as a constructional material, liquid metal technology, the characteristics of niobium, recent advances in atomic physics, moderators, welding, and the law. A directory of the atomic energy organisations of the world is given, but the " Who's Who " pages are restricted to British personalities. Clear print on opaque paper distinguishes the year book.

Mathematical Notes. By C. F. G. MACDERMOTT, M.A. Blackie and Son, Ltd., 17, Stanhope Street, Glasgow, C.4. Price 3s. 6d.

FOR students taking science or engineering studies and requiring something beyond " O " level mathematics, this booklet provides in skeleton form the facts likely to be needed. The economical, notelike form of the text suggests that only the gifted student would be able to dispense with tutorials on the subject. More care could well have been devoted to the composition ; " $0{\cdot}00125 = \log 1{\cdot}0025$ " is an unhappy equality to feature in an example, while " $f''(x), f^3(x)$, &c.," does not lack ambiguity. Nor is it easy to see that three-dimensional figures include planes.

Books Received

Linear Programming: An Explanation of the Simplex Algorithm. By Dakota Ulrich Greenwald. The Ronald Press Company, 15, East 26th Street, New York 10, N.Y. Price 3 dollars.

Basic Reinforced Concrete Design : Elastic and Creep. Second edition. By George Elwyn Large. The Ronald Press Company, 15, East 26th Street, New York 10, N.Y. Price 7 dollars.

System Engineering. By Harry H. Goode and Robert E. Machol. McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 75s.

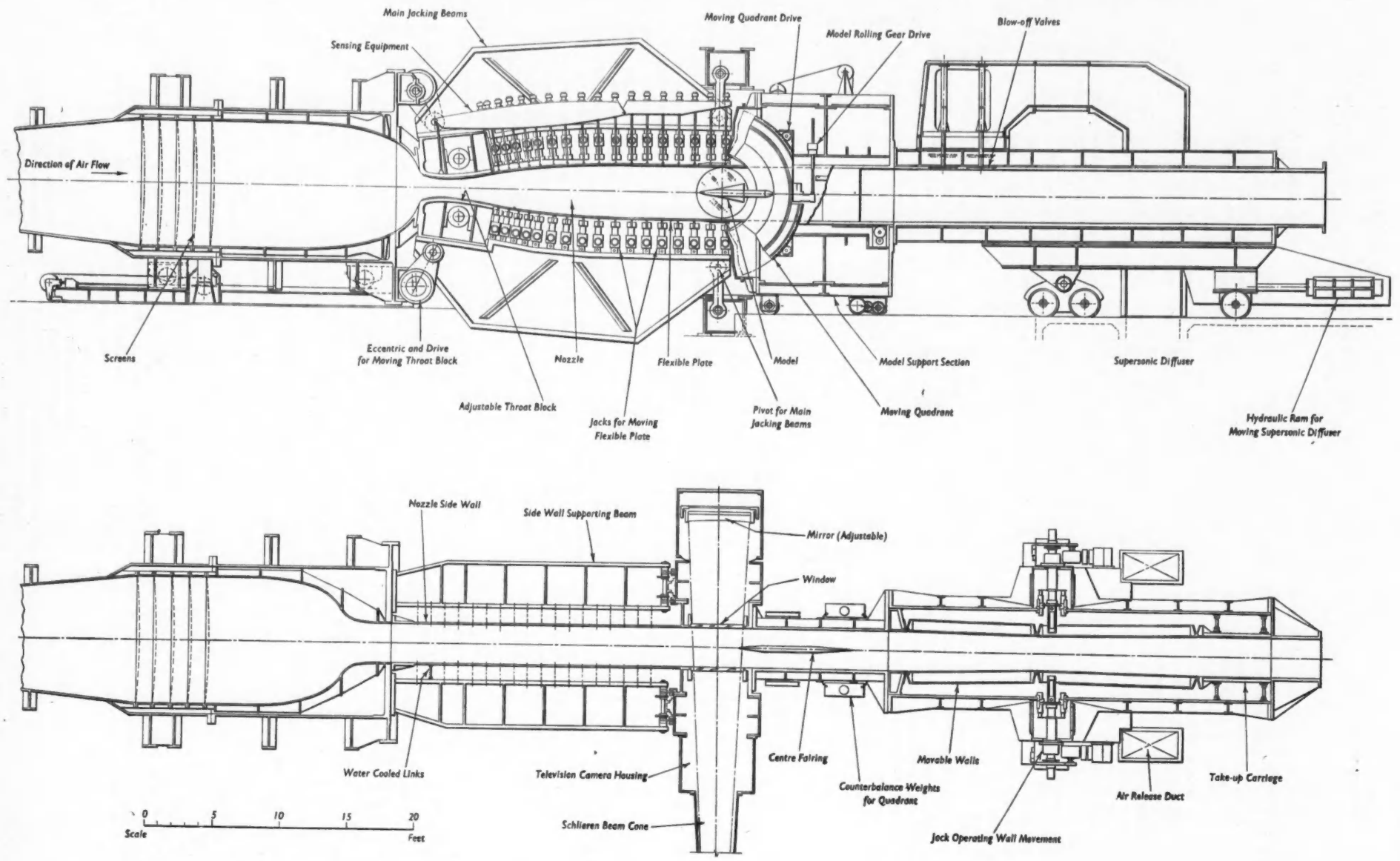
Steelplant Refractories, Testing, Research and Development. Second edition. By J. H. Chesters. The United Steel Companies, Ltd., 17, Westbourne Road, Sheffield, 10. Price 80s.

Polythene : The Technology and Uses of Ethylene Polymers. By A. Renfrew and Phillip Morgan. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 126s.

The Theory of Networks in Electrical Communication and Other Fields. By F. E. Rogers. Macdonald and Co., Ltd., 16, Maddox Street, London, W.1. Price 65s.

Radio and Electronic Components, Volume IV : Variable Capacitors and Trimmers. By G. W. A. Dummer. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 32s. 6d.

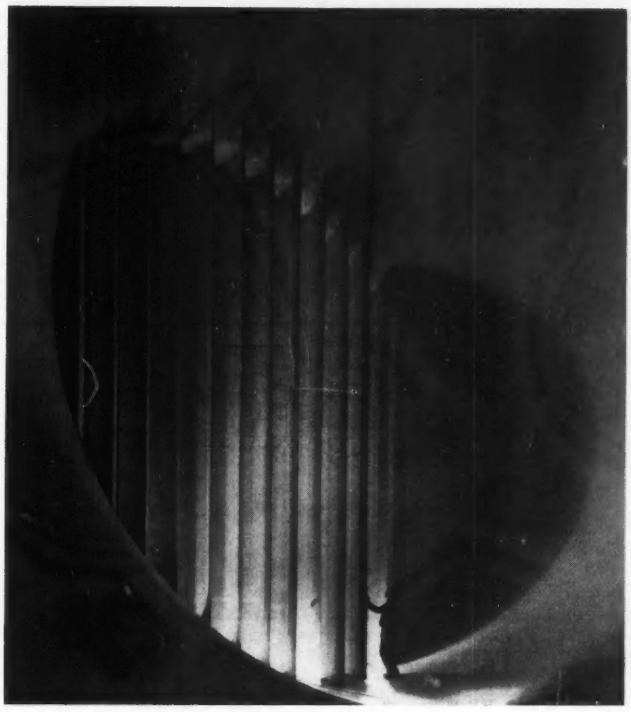
PROVISIONAL ARRANGEMENT OF 4 FT BY 3 FT SUPERSONIC TUNNEL AT R.A.E., BEDFORD



Opening of the R.A.E., Bedford

No. III—(*Concluded from page 54, July 12*)

On Thursday, June 27, the Minister of Supply opened the Royal Aircraft Establishment, Bedford, originally known as the National Aeronautical Establishment. It comprises, principally, large wind tunnel facilities and an extensive flying field having much special equipment and being able to represent carrier landings and launches. There is a variable-frequency power station with two 20MW gas turbine generators. The turning vanes at one corner of the 8ft by 8ft supersonic tunnel are seen here.



4ft by 3ft High Supersonic Tunnel

THERE is now under construction a tunnel of nominal speed range between Mach numbers 2·5 and 5. It will have available an overall pressure ratio of 17, and stagnation pressures will vary from 5 atmospheres absolute at M.2·5 to 14 atmospheres absolute at M.5. While the design of the compressors, coolers and associated equipment has been completed, that of the working section has not, and our drawing shows only a provisional arrangement. Since the total temperature of the working fluid is to be allowed to rise to 150 deg. Cent. to prevent liquefaction in the nozzle at high Mach numbers, the variable nozzle has not been included in the pressure shell, and the joints between the fixed side walls and adjustable top and bottom have to be made airtight. Two stages of sealing will be provided, the intermediate space being packed with dry air to exclude atmospheric moisture from the tunnel. It can be seen that a markedly different design from that of the 8ft by 8ft tunnel has been evolved, the subsonic part of the nozzle being defined by solid blocks, attached rigidly to the beams on which the variable geometry mechanism is carried. The beams are pivoted at the downstream end and moved by eccentrics to vary the throat depth. The flexible plate is again stainless iron, in this case 3ft wide, and the operating mechanism is also similar, but electric jack motors are used. The control mechanism is not yet finalised, the difficulty of defining required profiles within tolerances of about 0·001in in the presence of rapidly varying temperatures being severe, but the proposal shown has a set of pilot jacks mounted on a second beam which is not integral with the nozzle support beam, but articulated. Parts of the moving walls and control gear will be water cooled. The settling chamber upstream of the nozzle is fabricated of 1½in steel and stressed to support 14 atmospheres; however, the nozzle, working section and diffuser cannot be designed to accept such a static pressure, and to safeguard them against a drive failure while the tunnel is pressurised quick-acting relief valves are installed.

The supersonic diffuser has adjustable side walls of lengths 9½ft and 11½ft and can have throat widths between 34in and 16in; together with the subsonic diffuser and outlet casing, it can be moved a distance of 11ft downstream to allow the model support section, 10ft in length, to be removed to a rigging bay. Each support section has a 5½in thick sector carrying the sting and model, with the electrically controlled adjustments provided for pitch and roll.

Two similar sets of compressors are to be installed, and each will have two separate units which can be run either in series or in parallel. Each set will have a precooler, an intercooler, and an aftercooler; as mentioned above, the air temperature is allowed to rise at high Mach numbers and the coolers, able to maintain a stagnation temperature of 40 deg. Cent. at lower Mach numbers, must have their effectiveness reduced. This is done by by-passing the aftercooler and thereby saving pressure drop. A further by-pass spans the compressor installation complete in order to match the tunnel characteristics and suppress surging. The low-pressure compressors are eighteen-stage axials and the high-pressure eight-stage centrifugals; each set has a maximum speed of 3000 r.p.m., and is coupled to a 34,000 h.p. synchronous motor, while speed-increasing gears of a ratio of 3·22 allow the set to be brought up to speed by a six-pole, 10,000 h.p. induction motor. The synchronous motors can be fed from the variable-frequency power station, in which case the induction motors are regulated by liquid rheostats in the rotor circuits.

The induction motors are unable to run the compressors up to speed unless the tunnel pressure has been reduced by the four reciprocating pumps; when running, it is charged to the required pressure with dry air. Six-stage reciprocating compressors deliver air at 4500 lb per square inch to a series of coolers, the last using brine at 5 deg. Cent., and by this means the bulk of the water content is condensed; a final silica gel drier brings the humidity down to 0·00005 lb per pound of air. The dry air is stored at this elevated pressure in six strip-wound vessels, 45ft long by 48in internal diameter.

Other Tunnels

The 3ft by 3ft transonic and supersonic tunnel, based upon German compressors and motors, was described in our previous article on page 245, February 18, 1955. The 13ft by 9ft low-speed tunnel, a reinforced concrete structure, the vertical spinning tunnel, which also provides 50,000 gallons of elevated water storage above its pressure shell, and the high-speed laboratory, with four test bays running off a four-stage, 7500 r.p.m. centrifugal compressor that also pressurises the spinning tunnel, were described on page 279, February 25, 1955.

Gas Turbine Alternators

Still in course of erection at Bedford are the two English Electric 20MW gas turbine alternators, which provide variable-frequency power for the synchronous motors of the compressor drives, reduce the peak demand for 50 cycle power, and afford standby supplies.

The gas turbine cycle is illustrated diagrammatically in Fig. 10; it should be noted that the exhausts of the two h.p. sets are interconnected, so that the circuit is, in effect, 2SC/PLP. The reason for the use of two high-pressure lines instead of one is to reduce the length and complication of the pressurised hot gas ducting. The air flow to each h.p. unit is assumed to be the same, and the two combustion chambers are controlled as one. The pressure ratio is 16 and the turbine inlet temperature 890 deg. Cent. (1635 deg. Fah.); this temperature involves the use of distillate fuel, but is undoubtedly favoured in the case of a plant with relatively low utilisation.

The construction of the plant is on principles associated with English Electric turbines. The compressor rotor blades, thirteen stages in the l.p. and six, followed by a centrifugal stage, in the h.p., have simple wedge roots and are carried in deeply gashed grooves. The h.p. turbines which run at 8250 r.p.m., have two stages of free vortex blading, while the l.p. have six stages. The l.p. turbines are interesting machines in view of their very low speed, 3000 r.p.m. for the alternator and 2800 r.p.m. for the compressor rotor; they have horizontally split casings evocative of steam practice, secured with bolts and cap nuts. The massive rotor is hollowed for the most part of its length, the blades being carried on the solid upstream end; instead of the rotor being grooved, the blades are secured by circumferential bands. It is not known what materials are used for these components. The stator blades are stiffened extensively by lacing.

The fuel used is gas oil, which is injected through four atomising burners in each combustion chamber. Blast air to assist combustion is taken from the h.p. compressor outlet, cooled and compressed through a further 2/1 pressure ratio by a rotating-vane compressor passing 2 lb air per second. The gas oil is stored in two 500-ton oil tanks from which it is pumped to a 15-ton service tank built on the outside of the generating station wall 35ft above ground level, from which it is filtered, metered and gravity fed to the fuel pumps.

The alternators are two-pole, 11kV, three-phase machines. They operate over the 10-50 c/s range and voltage is proportional to frequency; constant power can be maintained down to 35 c/s. The alternator exciter sets are separately

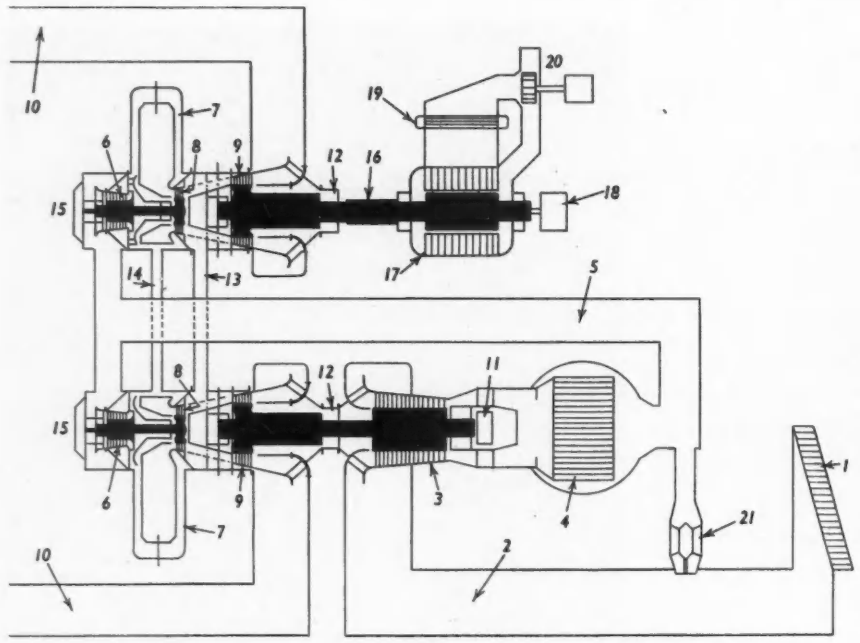


Fig. 10—20MW variable frequency gas turbine

motor driven at constant speed by 120 h.p. slipring induction motors, and the cooling fans for the conventional closed circuit air/water cooling circuit are driven by similar motors.

For starting, the engine-driven lubricating oil pumps, mounted on each h.p. set gearbox, are used as hydraulic motors, supplied from the constant output electrically driven lubricating oil pumps. Under running conditions, the electrically driven pumps supply oil to the thrust blocks. In this way the h.p. sets are driven up to 1100 r.p.m., at which point the fuel is switched on and ignited by a propane torch which itself is ignited by a sparking plug. The sets then become self-driving, the l.p. turbines bring the alternator and the charging compressor up to speed, the alternator excitation is switched on and the alternator put on the busbars ready for synchronising either with the second alternator or with the motor load.

The gas turbines are started locally from a desk at the h.p. end of each set, but once the alternator has been synchronised with the load motor, control is vested in the operator controlling the tunnel compressor drive. The driver retains an overriding control of the fuel and is responsible for the safety of the set in the event of an emergency.

On shutting down, each of the four gas turbine shafts is barred until the machines have cooled down. This is done electrically by a motor drive on the alternator shaft and electro-hydraulically on the other three shafts, but in the event of emergency, hand barring facilities are provided.

In the event of failure of the l.t. supply, two stand-by compressed-air-started 100kW diesel alternators are available to supply power for barring. These sets can also be used to supply the auxiliaries of the gas turbines during starting, which can thus be accomplished without assistance from the grid supply should the need arise.

Airfield and Services

The airfield is sited at Thurleigh, about 2½ miles from the Twinwood wind tunnel site, and has been developed from a World War II U.S. Air Force bomber station. Two of the original three runways have been retained and surfaced with concrete slabs and two new runways built, the east-west runway, originally intended to be 8100ft long, has been completed as a strip 10,500ft by 300ft, and is able to accept aircraft of all weights and undercarriage patterns.

Design and construction of all buildings and services has been the responsibility of the Ministry of Works. Air Ministry Works Department has undertaken the construction of runways, taxi tracks and airfield lighting system, and the Ministry of Supply the navigational aids, catapult and arrester gear installations.

The main development area, known as the Flights Area, is on the S.W. side of the airfield, where a group of hangars, workshops, offices, stores, laboratories, bulk fuel installation and canteen have been constructed. On the north side of the airfield is the Naval Air Section, with hangars, workshops, offices and installations for work on catapults and arrester gears.

An 11kV overhead line from the wind tunnel site at Twinwood provides power supplies up to 5000kVA and an 11kV underground ring main encircles the airfield with substations near load centres.

Space heating requirements in the Flights Area have been provided for by a central boiler plant comprising two coal-fired, water-tube, high-pressure hot water units, each of 15,000,000 B.Th.U. per hour rating at 350 deg. Fah. flow temperature and 250 deg. Fah. return temperature. A departure from usual practice was made in this case in that the plant was designed to work in the open without the protection of a building. Only the firing aisle is enclosed, in order to protect the operators. This method of construction is amply justified in these circumstances of this installation; cost estimates showed that a building enclosing the plant could only be justified by a saving in running and maintenance costs six times that which could be expected. The boilers, coal and ash handling plant can be seen in Fig. 12. Exposed lagging is waterproofed by means of a ¼in sheath of emulsified asphalt, trowelled on.

Heat distribution is by underground mains laid in foam concrete. Adjoining the boiler plant is an automatic fire pump installation serving a fire main system embracing the hangars and other buildings in the Flights Area. The pumps and an air-loaded accumulator keep the fire mains constantly charged at 150 lb per square inch for instant use with foam-making apparatus in the event of a serious petrol or oil fire. On the opening up of any hydrant on the system the pumps start automatically to maintain the pressure and can satisfy any demand up to 1000 gallons a minute, drawing water from a static water tank of 60,000 gallons capacity.

The largest hangar on the site, seen in Fig. 11, is an all-aluminium structure with a clear span of 200ft, a clear height of 50ft, and an overall length of 245ft. Radiant heating has been adopted for this and other hangars to minimise the effect of heat losses due to air change when doors are opened. The system used employs 1in bore steel tubes spanning the width of the floor at 12in centres and embedded in the concrete 3½in below the surface to give a floor surface temperature of 75 deg. Fah. This is supplemented by high-temperature, hot-water radiant panels installed along both sides of the hangar. Heating pipes are also embedded in the concrete under the tracks of the motor-operated hangar doors to facilitate operation under snow and ice conditions. To obviate any electro-chemical attack, aluminium-sheathed V.I.R. cables have been used for the electrical installation in the aluminium hangar, and the installation is constructed with flameproof enclosure to a height of 30ft above the floor.

On the south side of the airfield a new control tower has been built. A plenum system has been installed to maintain conditions favourable to mental alertness in the approach control room, which has no windows and considerable heat gain from equipment installed, and in the local control room on the top of the tower, which has large glazed areas resulting in high heat gain from solar radiation. The equipment incorporates a 20-ton refrigeration plant with direct expansion coils in the air circuit followed by an electric heater battery. It maintains conditions automatically at approximately 68 deg. Fah. dry bulb and 50 per cent relative humidity during summer and winter when outside conditions are within the limits of 30 deg. Fah. saturated and 80 deg. Fah. with 60 per cent relative humidity.

The local control cupola on the top of the tower gives an unrestricted view of all runways, taxiways and approaches. Control of the runway and instrument approach lighting which serve the two major runways is to hand, together with

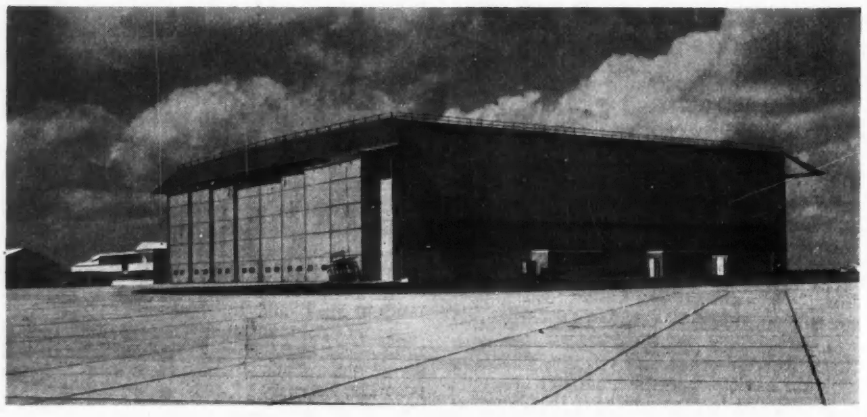


Fig. 11—The all-aluminium hangar has a clear span of 200ft. Radiant heating is provided by high pressure hot water pipes embedded in the floor

the control lights for vehicular traffic on the airfield. Control of movement on the airfield is further supplemented by police patrol vehicles which maintain radio contact with the local controller in the cupola.

An instrument landing system and camera recording equipment have been installed on runway 27 specifically for the use of the blind landing experimental unit for the development of associated automatic equipment, and leads to continuous approaches on this runway, which are against normal traffic when easterly winds prevail.

The approach control room is equipped with multi-channel CRD/F (cathode ray direction-finding), the R.A.E. angulator fixing system, two 10cm long-range radar consoles, two 3cm short-range search and P.P.I. talk-down consoles, and SLA 3 3cm precision approach equipment for talk-down to the runway; 50cm search radar is scheduled for installation later in the year and will be used as the primary search and circuit control radar as it is unaffected by weather returns and the moving target indication component minimises ground returns.

The equipment is arranged for handling from five opreating positions, each controller having his own v.h.f. R/T and telephone console, and with CRD/F repeater units adjacent to the search radar positions to allow early take-over from the main CRD/F position.

Flight information strips and meteorological information are conveyed from the ground floor by Lamson tubes and delivered at the approach liaison desk.

These aids are used to maintain a continuous radar watch on the test flight from take-off to operating altitude in all weathers, and on completion of the sortie the aircraft is fixed, brought into radar cover, then suitably positioned and brought down into the vicinity of the airfield for a visual circuit or a ground-controlled approach and landing. The runway approaches being unobstructed and the pilots highly experienced, bad weather minima are claimed to be very low.

The central-heating boiler installation on the tunnels site is oil fired to minimise the effects of ash and other combustion products in the vicinity of air intakes to wind tunnels. Hot water is circulated at high pressure to the buildings.

Water for all purposes is drawn from the River Ouse, and is softened and specially treated in the water-treatment plant on the tunnels site, to be suitable for drinking, to prevent "furring" in plant and pipes, and to minimise corrosion in coolers, boilers and pipes. For the large quantities of cooling water required by the wind tunnels at full power, water may be treated and stored at the rate of 30,000 gallons per hour for several hours per day, but no water is drawn from the river if in dry weather the river flow drops to 8,000,000 gallons per day.

Electrical power is supplied from Little Barford power station via a gas-pressurised underground cable, 2 miles in length, to the tunnel site, at 132kV, with maximum capacity of 75,000kW. The supply is transformed to 33kV before reaching the main substation, from where it is distributed by underground cables to the various buildings and overhead to the airfield, generally at 11kV. There are also 50kV and 6kV supplies to erstwhile German equipment.

Contractors

We list below some of the major contributors to the buildings and plant.

Twinwood Wind Tunnel Site General Services

Main access road and internal roads, Howard Farrow, Ltd.; storm water drains and sewers, Howard Farrow, Ltd., and George Wimpey and Co., Ltd.; 33kV switchgear, English Electric Company, Ltd.; 11kV switchgear, A. Reyrolle and Co., Ltd.; 25MVA transformers, Johnson and Phillips, Ltd.; 0·5/15MVA transformers, C. A. Parsons and Co., Ltd.; distribution cables, the London Electricity Board; central boiler plant, La Mont Steam Generator Company, Ltd.; heating mains, Matthew Hall and Co., Ltd.; water and fire mains, William Press and Son, Ltd.; fire pumps, The Pulsometer Engineering Company, Ltd.; water softening plant, The Permutit Company, Ltd.

3ft by 3ft Supersonic Wind Tunnel

Tunnel structure and working section, Whessoe, Ltd.; re-installation of German compressors, Markham and Co., Ltd.; reinstallation of German electrical equipment, English Electric Company, Ltd.; rewinding of German d.c. motors, Baldwin and Francis, Ltd.; installation of power and control cables, The London Electricity Board; air drying plant, Silica Gel, Ltd.; compressor/evacuator plant, Alley and MacLellan, Ltd.; cooling tower, Film Cooling Towers, Ltd.; electrical services, The London Electricity Board; buildings and plant foundations, George Wimpey and Co., Ltd.

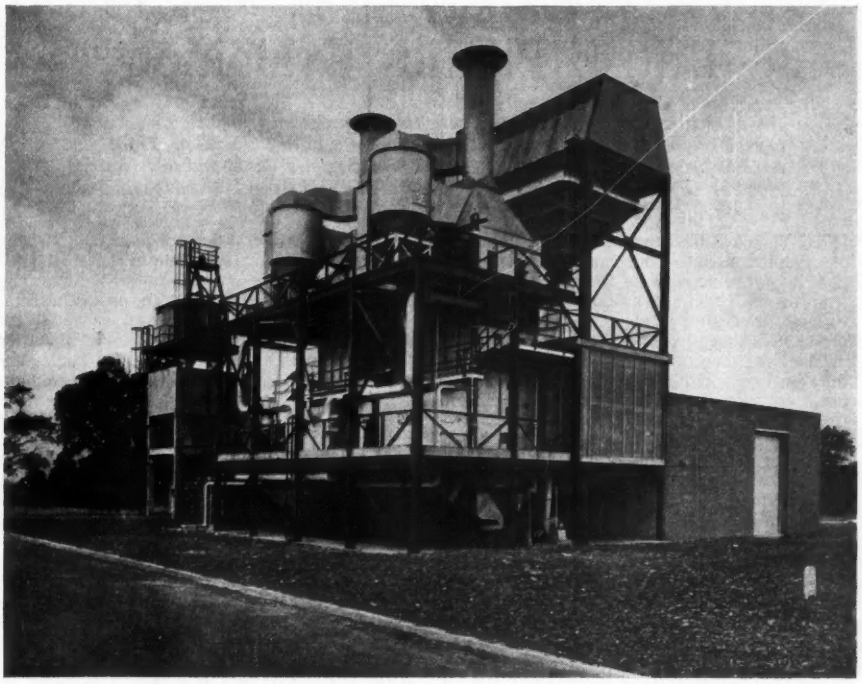


Fig. 12—The open-air boiler plant has chain grate stokers and induced draught furnaces. The ash handling plant can be seen on the left

High-Speed Laboratory

Main compressor plant, The British Thomson-Houston Company, Ltd.; charging compressor/evacuator plant, Alley and MacLellan, Ltd.; air drying plant, Birlec, Ltd.; air mains, Matthew Hall and Co., Ltd.; air valves, J. Blakeborough and Sons, Ltd.; electrical services, The London Electricity Board; building and plant foundations, George Wimpey and Co., Ltd.

Vertical Spinning Tunnel

Pressure vessel and internal tunnel structure, Whessoe, Ltd.; electric drive to fan, English Electric Company, Ltd.; hydraulics for fan pitch control and model launching gear, Automotive Products Company, Ltd.; periscope optical system, Barr and Stroud, Ltd.

13ft by 9ft Low-Speed Wind Tunnel

Buildings and reinforced concrete tunnel shell, F. G. Minter, Ltd.; steel fan section, Head Wrightson and Co., Ltd.; electric drive for fan, Metropolitan-Vickers Electrical Company, Ltd.; screen hoisting gear, Major Equipment Company, Ltd.; installation of German variable high-frequency generating plant for slip-stream model motors, English Electric Company, Ltd.; compressor/evacuators for boundary layer experiments, James Howden and Co., Ltd.; electrical services, The London Electricity Board.

8ft by 8ft Supersonic Wind Tunnel

Tunnel shell and main air cooler, Whessoe, Ltd.; main compressor and electric drive, English Electric Company, Ltd.; 11kV and 3·3kV switchgear, English Electric Company, Ltd.; flexible plate nozzle, supersonic diffuser and associated hydraulics, Costain-John Brown, Ltd.; machining flexible plate, Le Societe des Forges et Ateliers du Creusot; electrical control system for nozzle and supersonic diffuser, The General Electric Company, Ltd., Research Laboratories; rewinding of German d.c. motors and generators, Baldwin and Francis, Ltd.; air drying plant, Silica Gel, Ltd.; main charging compressors, Daniel Adamson and Co., Ltd.; trimming compressors and evacuators, James Howden and Co., Ltd.; cooling towers, Film Cooling Towers, Ltd.; circulating water pumps, Pulsometer Engineering Company, Ltd.; air and water pipework, Whessoe, Ltd., and Simmonds and Hawker, Ltd.; air and water valves, Alley and MacLellan, Ltd., and J. Blakeborough and Sons, Ltd.; model strain gauge calibration gear, Sir Howard Grubb Parsons and Co., Ltd.; periscope optical systems, Barr and Stroud, Ltd.; closed circuit television cameras and monitors, Pye Telecommunications, Ltd.; buildings and tunnel foundations, Higgs and Hill, Ltd.

Variable-Frequency Generating Station

Gas turbine generating plant, The English Electric Company, Ltd.; fuel storage installation, Costain-John Brown, Ltd.; 65-ton crane, Babcock and Wilcox, Ltd.; electric services, The London Electricity Board; building and plant foundations, Higgs and Hill, Ltd.

4ft by 3ft High Supersonic Speed Wind Tunnel (Under Construction)

Main compressor plant and electric drive, Metropolitan-Vickers Electrical Company, Ltd.; adjustable nozzle, model support section and supersonic diffuser, The General Electric Company, Ltd. (Fraser and Chalmers Engineering Works); high-pressure compressors and air drying plant, Harland and Wolff, Ltd.; high-pressure dry air storage vessels, Vickers Armstrong, Ltd.; tunnel evacuators, Reavell and Co., Ltd.; cooling towers, Davenport Engineering Company, Ltd.; cooling water pumps, Sulzer Brothers, Ltd.; cooling water and high-pressure air pipework, Stewarts and Lloyds, Ltd.; buildings and plant foundations, John Laing and Co., Ltd.

Thurleigh Airfield

Buildings and civil engineering work, John Laing and Co., Ltd.; aluminium hangar, Hawksley S.M.D., Ltd.; steel frame hangars and fencing, Boulton and Paul, Ltd.; central boiler plant, La Mont Steam Generator Company, Ltd.; heating mains, Matthew Hall and Co., Ltd.; fire and water mains, William Press and Son, Ltd.; fire pump installation, Gwynnes Pumps, Ltd.; bulk aviation fuel storage installations, Matthew Hall and Co., Ltd.; 11kV overhead line from Twinwood site, Enfield Cables, Ltd.

High-Temperature Cements

Cements have been developed in the past by Bristol Aero-Engines, Ltd., for securing wire resistance strain gauges to components for testing at high temperatures. They have also been used to attach electric heating elements to components. Two of these preparations, "Brimor" U.527 and U.529, are now available commercially from the Morgan Crucible Company, Ltd. They are basically similar in composition, but the former is of medium hardness, while the latter is very hard and tenacious and has a higher bond strength.

The cements are suitable for heat-resistant steels and "Nimonic" alloys, with which they can operate at temperatures up to about 750 deg. Cent. They can also be used quite easily with low alloy steels, cast iron, and some non-ferrous materials such as brass, titanium, copper and aluminium alloys. Adhesion is less satisfactory on non-ferrous metals than on steel as the surface oxidation occurring on the former at high temperatures has an unfavourable influence on the bond between the cement and the metal. The cements cannot be used successfully with foil gauges having strippable plastic backing.

The method of use with wire resistance strain gauges is as follows. The cement is brushed on to the roughened and degreased surface of the component to be tested. A thin layer 0·004in to 0·005in thick is formed, air dried, and then cured up to 250 deg. Cent. (if cured below 200 deg. Cent. the cement will dissolve in water, and will eventually soften if exposed to atmosphere). The cements are not air hardening and baking is necessary to prevent softening of the undercoat when applying the next layer. The gauge grid is clamped down on the undercoat, pressure being applied by a suitably shaped rubber pad, and the exposed portions are coated with cement. Air drying is followed by local heating. When the cement is hard, the paper backing is soaked in acetone to soften the "Durofix" adhesive, and then removed. After careful washing with acetone to remove all traces of adhesive, the exposed centre portion of the grid is cemented over, air dried, and baked up to 250 deg. Cent. A final overcoat is applied, and this is cured up to 350 deg. Cent.

The cements are said to have a shelf life of several months if carefully used. It is claimed that good bonding to metals or ceramics, mechanical strength, resistance to thermal shock, and good electrical insulation are all retained at temperatures up to about 750 deg. Cent.

British Plastics Exhibition

An international exhibition and convention organised by British Plastics *was opened on Wednesday, July* 10, *by the President of the Board of Trade, and remains open until to-morrow. The exhibition occupies the Grand and National Halls at Olympia. We describe some of the techniques and products displayed.*

THE stands at the International British Plastics Exhibition and Convention represented all phases of the activity of the plastics industry from the evolution and production of materials, through processing and packing, to finished products of great diversity. It appeared that the products were predominantly articles that could only be made in plastics, and that it was less usual for organic material to have taken the place of, say, metal in the same application. This is not surprising in view of the distinctive properties of plastics materials, one of the novel applications of which on show was the " Neway " translucent door. This resembled the established flexible rubber doors which can be brushed aside in passing, but had ¼in thick pale blue transparent panels with a grained finish, so that it was possible to distinguish an object approaching the far side of the door. The material is classed as self-extinguishing. An example of the opposite trend was a large solid-propellant rocket motor case displayed by Bristol which, instead of their customary welded high tensile steel, consisted of glass-reinforced resin. It may be surmised that, even if the structural efficiency as a pressure vessel is not superior, the thick-walled cylinder proves a stiffer and less resonant body for a supersonic vehicle. Such an application, like the manufacture of drop tanks, may also benefit from the much closer tolerances on the final envelope obtained when forming from sheet is discarded : plastics drop tanks have been demonstrated to possess higher buffet limits due to this effect. A sectioned model of a large drop tank showed its sectional construction, with baffles across the centre section and a float valve to allow flight to continue at negative *g*.

One conspicuous instance of resin rivalling metal is in the construction of motor bodies. Several examples were to be seen, but the Arnott car was typical in using plastics merely to provide a distinctive shell for fitting to a conventional frame. There appear to be few cases even of attachments being bonded into the body, and the virtues of a complex curved plastics shell to stiffen the stressed structure are not exploited. (One exception to this, however, is the translucent van roof made by Cascelloid, Abbey Lane, Leicester, which has a series of identical aluminium channel-section transversals, with cast end fittings, actually bonded into the one-piece roof.) This feature of the designs, surprising in such a demanding application as a light motor vehicle, may be explained by the fact that the cost of a metal body is largely represented by the tools, and therefore costly engineering effort is lavished on an individual design, while the plastics bodies are expensive because of their high labour content, and many different designs are being built in relatively trifling quantities. The possibility of an attractive modification to this situation is held out by the appearance of a spraying process for glass-fibre reinforced resins, which might be expected to give a significant advantage to firms producing sufficient components to afford the plant, while the investment in moulds for one individual design is not necessarily increased. The spraying process, while evolved principally to avoid the laborious process of hand lay up, is claimed also to afford a superior product, since the reinforcement is uniform and completely random all through, whereas the use of fibre mats introduces discontinuities, particularly if complex curvature is concerned. The spraying plant, developed by M.A.S. Kunststoff-Vertriebsgesellschaft M.B.H., Düsseldorf, and displayed on the stand of Metropolitan Plastics, Ltd., Glenville Grove, Deptford, S.E.8, is seen in use in Fig. 1. The actual spraying takes perhaps three or four minutes to deposit a 0·04in layer over 10 square feet, after which hand rolling and curing follow in the usual way.

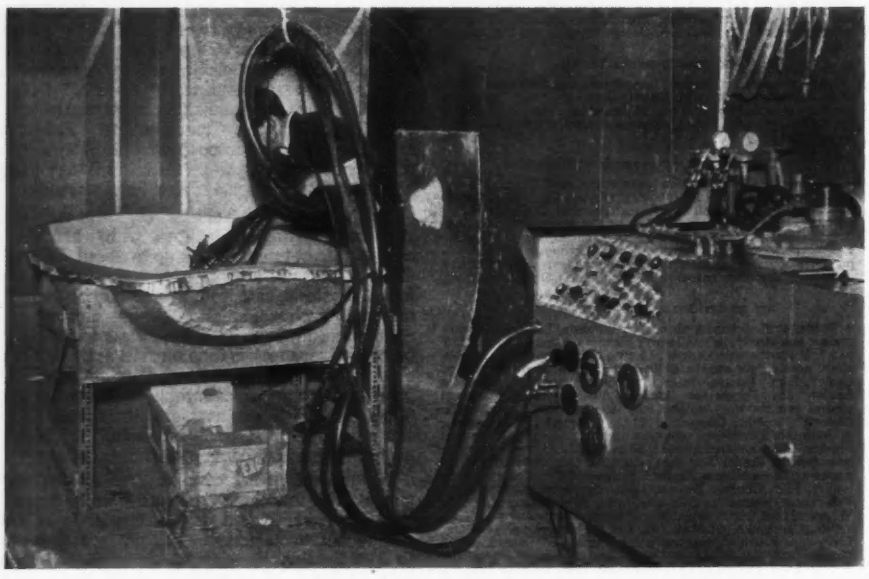


Fig. 1—A boat hull being made of glass-reinforced plastics by spraying into the mould

The plant, which is mobile on castors, needs to be connected to compressed air and electricity supplies. It has two containers for resin, one for solvent, and a bag for a fibre roving. The fluid vessels are pressurised with air, while the glass fibre is delivered by rolls electrically driven at infinitely variable speeds to a cutting mechanism, the speed of which determines the fibre length—it is then carried by a blast of air from a fan along a large hose to the gun. The gun has either one or two spraying nozzles built into it, resin and chopped fibres being delivered separately and mixed only after leaving the gun : two sprayers are used for cold setting resin, one of the two resin containers having catalyst mixed with it and the other accelerator. By this method roughly similar deliveries from the two vessels are required and the difficulty of proportioning is reduced : the delivery of the two spray nozzles can be varied up to a ratio of 15:85. Any filler, such as silicon dioxide to endow thixotropic properties, can be mixed into one container, which is then fitted with a stirring mechanism, driven by an air motor or by hand if up to 50 per cent of heavy fillers such as quartz are in use for insulating work. The gun can either have trigger control for delivering either or both fibre and resin, or be electrically controlled to deliver a pre-determined charge, thus reducing the need for the operator to assess the deposit attained. In this case only low-voltage leads run to the gun.

The tubing and guns can be cleaned with solvent by making appropriate connections, and it is found that with the comparatively long holding times of modern resins this needs to be done each evening, while the resin containers should be cleaned out weekly. An air heater can be incorporated in the plant to expedite the polymerisation of cold-setting resins, and the control equipment for it is part of the standard circuitry.

Apart from the filling of moulds, other applications for the M.A.S. plant have been the application of resin to metal panels to prevent their vibrating, the insulation of buildings, the lining of acid containers, and even the sealing against dust of the concrete run-up areas of aerodromes used by jet aircraft.

Another distinctive equipment of Continental origin was the Wirth electrostatic flock depositor, shown by F. J. Edwards, Ltd., 359-361, Euston Road., N.W.1. This gives a very high potential to dielectric fibres leaving it, so that when sprinkled upon an adhesive non-conducting surface they stand upon it roughly parallel : it is claimed that this technique can be used instead of weaving to manufacture carpets.

Other interesting products made by depositing plastic compounds upon metal were displayed by Durable Plastics, Ltd., Guildford, Surrey, whose exhibit included a sticky preparation of Turkish Delight which was seen to be readily removable from a tray surfaced with p.t.f.e. (polytetrafluoroethylene). Of more technical interest was a vehicle leaf spring which, to suit it for use in extremely cold climates where conventional lubrication would be impracticable, had had the upper surface of each leaf covered with nylon. It was claimed that each leaf could be completely covered, thus eliminating the problems both of lubrication and corrosion, at a cost probably less than that of a gaiter.

Other products intended for arduous service conditions were the military aircraft components on the stand of Marston Excelsior, Ltd., Fordhouses, Wolverhampton. These included one very long fairing for the tip of an Avro " Vulcan " fin ; it was reinforced with " Durestos " which, while not so strong as glass fibre, is more economical and adequately transparent to lower radio frequencies. There was also shown the radome of the Gloster " Javelin," 8ft long and 5ft diameter at the rear, which weighs 160 lb. It is of sandwich construction, with a 0·5in core of expanded ebonite, covered on each surface with glass fibre reinforced polyester resin to give a thickness of 0·6in. The outer surface is a neoprene compound for resistance to erosion by rain. These radomes, it will be recalled, are ogive in shape, coming to about ¼in diameter at the nose.

Plastics radomes are confined by their poor heat resistance to low-supersonic aircraft and to missiles of short flight times, and for more advanced military applications there are needed such nose cones as that shown by the Mycalex Corporation of America, 125, Clifton Boulevard, Clifton, N.J. This ceramoplastic component was moulded in " Supramica " 555, which will endure temperatures up to 950 deg. Fah. This and allied materials enjoy coefficients of thermal expansion close to that of stainless steel (so that it is possible to reinforce a radome by metal at a depth of a quarter-wavelength) and they are machinable on conventional tools with copious water lubrication. The radomes are actually formed by a precision moulding technique dispensing with the expense of grinding large surface areas, and the one displayed had been gated into the nose : it is interesting to note that a requirement has now arisen that the radomes be impermeable to helium, and a ring gate in another location has now been adopted. Ceramoplastic radomes are much superior in rain resistance to laminated

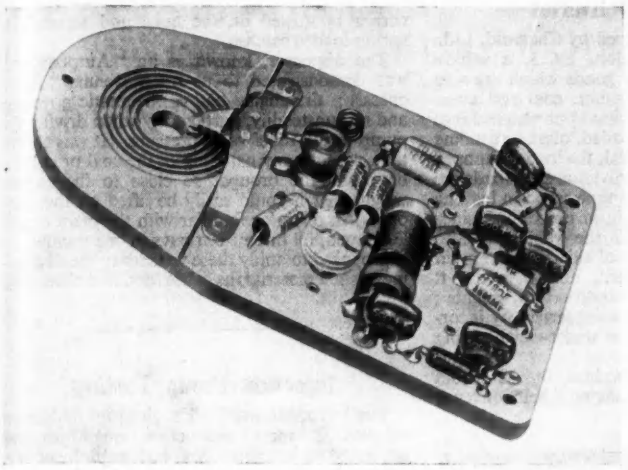


Fig. 2—A highly stable continuously tunable oscillator with a ceramo-plastic base ; it employs printed circuitry and is assembled automatically

plastics, but, we are informed, inferior to such hard materials as zircon.

The origin and applications of these ceramo-plastics are intriguing. Whereas Mycalex Company, Ltd., was organised in England to develop and market glass-bonded mica as an outlet for the mountains of mica trimmings accumulated in India, the corporation, wholly American-owned since 1941, determined to synthesise mica both for strategic reasons and in the expectation of superior properties. In fact, synthetic micas are true crystallographic analogues of natural micas but, as in fluor-phlogopith, have a fluorine ion in place of the hydroxyl : in this case crystals of conveniently large sizes can be obtained directly from a melt at atmospheric pressure. It is the hydroxyl group which is displaced at high temperatures, and therefore the synthetic material has superior heat resistance : the bonding of synthetic mica rather than muscovite with glass correspondingly results in an increased thermal stability. The dimensional stability is so marked that surfaces finished optically flat remain so, while one Doppler direction finder employs a capacity commutator incorporating two 14in diameter discs of " Supramica " 500 running at 14,000 r.p.m. with a face-to-face clearance of 0·006in. Another incidental advantage of the resistance to heat is that printed circuit techniques involving high firing temperatures, such as silk screen printing of silver, can be employed.

Fig. 2 illustrates an extremely stable oscillator exploiting the properties of ceramoplastics. It is part of a vehicular receiver, and eliminates the need for a number of crystals by affording a stability better than 150 parts per million from 32·5 to 57·5 Mc/s : this performance allows 50 kc/s adjacent channel operation, effectively doubling the channels available, and is maintained between −65 deg. Fah. and 170 deg. Fah. ambient, the oscillator running in an oven at 175 deg. Fah. The oscillator is automatically assembled and employs printed circuits : the tuning element is the silver spiral which can be seen embedded in the dielectric. Apart from low electrical losses in normal applications, these synthetic materials have the further advantage that, because metal parts can be bonded into them, corona is not experienced in high altitude operation.

Germanium Rectifier Assemblies

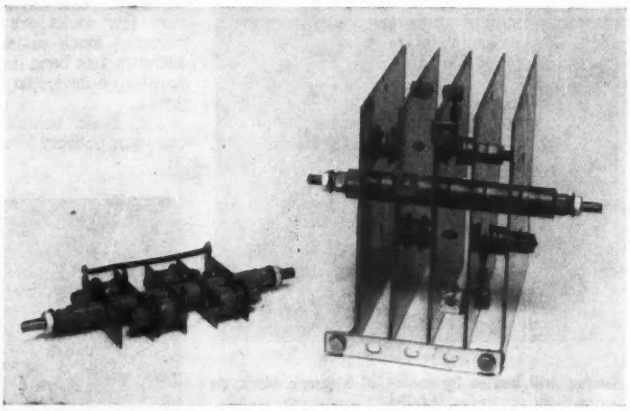
A NEW range of germanium rectifier stacks with an operating efficiency specified as more than 95 per cent is now available from The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. The range is based on medium-power germanium diodes, " GEX541," in various series, parallel and series-parallel arrangements. The rectifier stacks provide direct current supplies for medium power requirements up to about 30kVA. Compared with the older designs of semi-conductor rectifier, the stack of " GEX541 " units is claimed to be smaller and lighter for similar power ratings, and to have better regulation characteristics and constancy of performance under adverse climatic conditions.

The rectifiers are available in a range of standard stacks for operation up to a maximum ambient temperature of 55 deg. Cent. The addition of cooling fins to a stack will increase the power-handling capabilities. The device is suitable for use in any power-rectifying circuits for single-phase, three-phase or six-phase operation. Power requirements of up to about 30kVA are economically handled by finned units using series and parallel diode connections.

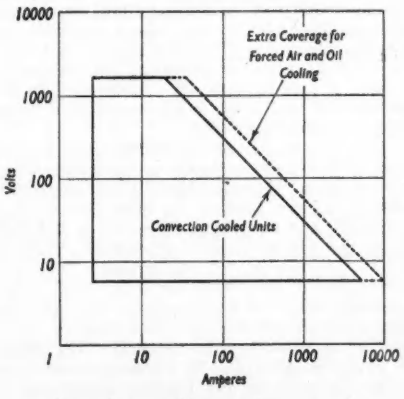
The maximum size of the units built up from " GEX541 " diodes will depend upon a number of factors. For example, the total voltage drop across a three-phase bridge rectifier using about twenty germanium diodes per arm is of the order of 20V, which is the average value for the voltage drop across a mercury-arc rectifier. On the basis that the peak-voltage rating for a single-diode is 80V, the total applied peak voltage must exceed 1600V (i.e. 80×20), before the efficiency of the mercury-arc rectifier matches that of the germanium. The maximum current limitation is usually determined by the economics of building a stack using the number of parallel diodes necessary to achieve the required current rating. Because the high efficiency of germanium is maintained at extremely low voltages, it is possible that the tendency in many installations will be away from the high-voltage lines, which were used to obtain a high efficiency from mercury-arc rectifiers, towards lower voltage germanium rectifiers.

In the finned series each diode is mounted on a 4in square aluminium cooling fin, and in the unfinned series each diode is mounted on a small tinned steel mount. As illustrated here, both series are of spindle-type construction and are suitable for operation with either natural convection, forced air, or oil, cooling. On the accompanying diagram the solid line graph shows approximately the range of current and voltage coverage of normal convection cooled stacks using the " GEX541 " diode, whilst with forced air or oil cooling the range can be extended to that shown by the dotted line.

The " GEX541 " rectifier is a p-n junction diode manufactured by an alloy process under controlled conditions to ensure reliability. With derating, the diode is suitable for operation up to a maximum ambient temperature of 55 deg. Cent.



The single-phase bridge assembly of germanium rectifiers on the left has a nominal d.c. output of 48V at 5A (35 deg. Cent. ambient) or 2A (55 deg. Cent. ambient). On the right is the finned version of this assembly ; it has a nominal d.c. output of 48V at 12A (35 deg. Cent. ambient) or 4A (55 deg. Cent. ambient)



Approximate volt/ampere coverage of " GEX541 " rectifier units

Because of the very low forward resistance the percentage power loss in the device is extremely small and power transfer efficiencies in excess of 95 per cent are achieved. The high efficiency is reflected in the regulation characteristic, which is better than 2 per cent from zero to full output current at the maximum rated voltage, most of this variation occurring between zero and about 25 per cent of the full output.

A germanium rectifier stack for three-phase bridge operation and cooled by natural convection has a power-to-weight ratio of 1·6kW per pound. For an equivalent power output the germanium stacks occupy about 30 per cent of the volume of selenium rectifiers. There is no increase in forward resistance with life so that the need for additional transformer tappings, and the associated adjustments, to cater for this ageing effect is eliminated.

The germanium diode is hermetically sealed in a small copper cup to ensure that the operative part of the device is shielded from the effects of moisture. It is possible, therefore, to operate the device under adverse atmospheric conditions, restricted only by the maximum ambient temperature stipulated.

The new rectifier stacks are designed for a wide field of application, including, for example, battery chargers for electric vehicles, emergency lighting systems, telephone systems, substation operation and protection circuits, power supplies for d.c. motors, welding and electro-plating equipment, and lightweight d.c. power supplies for aircraft equipment.

Precision Locating Instrument for Drilling Holes

AN instrument, known as the " Holemaster," has been developed by Euco Tools, Ltd., 44, London Road, Kingston, Surrey, to provide a means of accurately locating the centre distances when drilling holes in toolrooms and machine shops, without the use of a jig borer. The instrument is basically a longitudinally slotted and precision ground steel parallel with a hole bored precisely in line with the slot at each end. Special drill bushes, which are made to a close sliding fit in the slot of the parallel, have a flange at one end and a threaded extension at the other. These bushes can be set at any required point along the slot and locked there by a tightening nut on the screwed extension. Similar

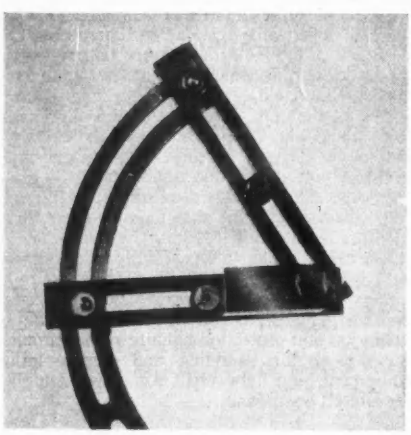
bushes are provided for insertion in the holes in the end of a parallel. A range of semicircular and circular steadies with curved slots are available for attachment to the ends of parallels to permit them to be arranged in sets to suit a particular job and locked in any required angular relationship.

For drilling holes in line a single parallel can be used when the required centre distances are less than 4in. In this case a drill bush in the hole at one end of the parallel can be used for

Setting drill bushes by means of a gauge block on parallel

locating one hole and sliding bushes for the remaining holes. When the bushes have been placed in the slot the hole centres are located either by measuring over or between the flanged heads, or by using ¼in diameter plugs in the holes in conjunction with slips or micrometers, or by placing slips between the heads, as shown in one of our illustrations. Accurately ground ¼in drills are then used to drill pilot holes in the work, and these holes can then be enlarged in the usual way. For long lines of holes or those spaced some distance apart sets of parallels can be joined together in line, using the pivot drill bushes at their ends to hold and clamp a grooved coupling plate.

When it is required to drill holes at angular dimensions from a central point the ends of two or more parallels are connected at one end



Parallels used in conjunction with radius steady for drilling holes in angular relationship

through the pivot drill bushes, and their opposite ends attached through the pivot bushes to the curved slotted steady. The drill bushes are then set with plugs or slips as described above. To drill holes at accurate centres on a pitch circle a circular steady is used with three parallels connected at the centre, where the pivot bush is located on the work by a plug in a previously drilled hole. With the bushes in the required position on their parallels the first three holes are drilled. Subsequent drilling positions are located by turning the assembly on its centre plug and locating one of the bushes by a plug in one of the previously drilled holes, continuing until the ring of holes is completed.

Discrete Deliveries

THERE has been introduced by Charrold, Ltd., 40, Trinity Square, London, E.C.3, a vehicle equipped to carry in bulk goods which are sold in weighed bags—in particular, coal and coke. Instead of the material having to be weighed into bags when the vehicle is loaded, often in a siding or bay where space is limited, the load is dumped into a hopper body and individual sack loads are made up as required. The time saved in loading is not completely lost again in unloading, since manhandling of sacks off the vehicle is also obviated. One advantage of this system is that very few sacks are needed, and therefore it becomes much easier to control tare weights ; accuracy has been further safeguarded by incorporating a device to prevent under-weight being given.

The basic vehicle resembles the Charrold conveyor delivery lorry in having a belt conveyor

A filled sack has been delivered at shoulder height. Behind it can be seen the weighing machine, and below that the end of the conveyor. The second man has his right hand on the sack lift control and in his left one of the special sacks that hooks on to the carrier

built into the bottom of its hopper. Since the rate of handling is much lower than in the bulk delivery case, it is not considered necessary to be able to shut off parts of the body to reduce degradation of the fuel, but there is an inverted trough above the hopper bottom to prevent the bulk material resting heavily on the conveyor. At the rear of the vehicle a hand-operated flap, spring loaded "open" or "shut," closes the conveyor gallery.

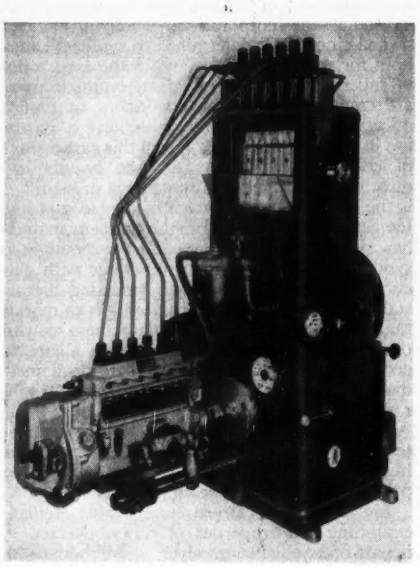
Built on to the rear of the body is an approved weighing machine, on which is hung a carrier for the special bag. The load is fed into the bag by hand control of the conveyor until the balance tips. Movement of the balance actuates an electric interlock and allows a second control to be selected to raise the carrier and bag to shoulder height for final delivery. A counter displays the number of bags lifted in an individual delivery and also a running total.

The construction of the vehicle again follows that of the Charrold lorry, all auxiliaries being driven by hydraulic motors. Early experience with the lorry showed the need for efficient filtration, and the pump, driven by a jackshaft from the gearbox, draws through a Purolator filter. The system runs on hydraulic fluid, and a pressure of about 15 lb per square inch gauge is maintained in the return side. A Cockburn motor drives the conveyor belt through worm gearing, and two rams lift the sack off the weighing machine, controlled by a three-position lever. Other controls at the loading station are a Bowden cable hand throttle and a lock for the weighing machine. For travelling, the bag carrier is stowed on the hoist and secured by spring-loaded catches.

The dispenser, known as an "Autobagger," was demonstrated to us on a Dennis "Pax" chassis ; the engine had a pneumatic governor and ran unsteadily, particularly when driving the pump to full relief valve pressure. It was shown that, without any handling of the coal or coke, a bag could be brought so close to the correct weight that it could easily be lifted on the scale pan. An operator familiar with the plant can, it is claimed, fill three 1 cwt bags in one minute. It is proposed to apply these vehicles to the dispensing of such materials as cattle food and chemicals.

Injection Pump Testing

THE introduction of oil engines by makers of vehicles in mass production quantities has generated a demand for test equipment for service stations that handle only a small proportion of oil-engined vehicles, probably all with similar engines. To meet this need the Merlin Engineering Company, Ltd., Halifax, Yorks, has introduced a bench model fuel pump test machine which, in its basic form, is particularly inexpensive. In this form it is able to test four- and six-cylinder pumps with pneumatic governors, providing, as it does, a choice of speeds of 200, 600 and 1000 r.p.m. A set of six balanced



The bench model test machine in action: the tachometer faces the pump, the fuel feed pressure gauge is beside the speed variation handwheel, and the automatic calibration control and indicator are on the side cover

test injectors is provided, and an automatic trip mechanism performs calibration over exactly 100, or a multiple of 100, revolutions.

For checking pumps with built-in governors, expanding pulley variable speed control with a range from 175 to 1250 r.p.m., and a tachometer, may be specified. Another extra is a fuel delivery pump able to develop sufficient pressure in the pump gallery to pass fuel through the delivery valve of any element whose plunger is below the point of commencing injection. By turning the pump by hand until such passage ceases, the commencement of injection may be timed, it is claimed, within two minutes of arc. For phasing, a scale of degrees can be clamped to the drive shaft. This system of high-pressure phasing and timing is believed to be the most accurate and faster than many others.

The machine is provided with a paper element filter in the fuel supply, and has a 1½ h.p. motor normally wound for three-phase, 50 cycle, 220/400V supplies. It will test all "A" size pumps, including C.A.V. and Hartford distributor pumps, "AA" size pumps and "B" size pumps, again including any "D.P.B." models, with up to 7·5mm bore plungers.

Industrial and Labour Notes

Economic Prospects

Last Friday afternoon, the Chancellor of the Exchequer, Mr. Peter Thorneycroft, addressed the National Production Advisory Council.

After some comments on Government expenditure and public and private investment programmes, the Chancellor recalled that last year industrial production barely rose, but that wages went up by 7 per cent and profits by 3 per cent. Since April, 1956, he added, retail prices had risen by only 2 per cent. This year, however, the Chancellor continued, there had been a further batch of wage increases of the order of 5 per cent, and in such circumstances, of course, price rises were inevitable. The country was suffering, the Chancellor observed, from an "internally generated price rise." He agreed that wages clearly must rise in an expanding economy, and should rise, perhaps, "a little faster than the more cautious spirits would deem to be wise." But, the Chancellor emphasised, when they rose out of all relation to production, we were "inflicting an injury upon ourselves."

The Chancellor then spoke about the "idea of some impartial body to produce an independent analysis of the related problems of incomes, costs and prices." Such a body, he said, would not be a wages court, nor a "super national authority," and it would not deal with individual wage claims. But it might well be that a body of the kind could play an important part in keeping before the country the essential facts of the economic position. It was worth noting, the Chancellor thought, that, at the recent meeting of the International Labour Organisation, the representatives of twenty-two other nations supported the idea of "an approach upon these lines." The Government had thought it right to take the views of employers and trade unions before making a final decision on the matter. Obviously, the Chancellor remarked, the final decision must be for the Government itself, but the talks already started would be pursued. At the end of his speech the Chancellor urged that "we ought to look at all these matters in their true perspective." There was, he said, more sound investment going on in this country than ever before; our exports were holding up pretty well in world markets, and the balance of payments outlook, on the best estimates that could be made, was not unfavourable. All these things, however, could be frustrated unless the process of rising prices was halted.

Overseas Trade

Provisional figures for the United Kingdom's overseas trade in June give the value of exports as £275,800,000, which was £27,000,000 below the figure for May. In the first half of this year, exports averaged £281,200,000 a month, which was 6 per cent higher than in the corresponding period of 1956. The value of imports in June was £324,000,000, which was £51,000,000 less than in May. The average monthly value of imports in the first half of this year was £350,100,000, which was 6 per cent above the average for the comparable period of last year, though it should not be overlooked that arrivals delayed in the closing weeks of last year accounted for about a quarter of the increase. Re-exports in June were valued at £10,100,000, which brought the monthly average for the first half-year to £11,500,000. This was 14 per cent lower than a year earlier. The Board of Trade says that in the first half of this year the visible trade deficit averaged £57,300,000 a month. This was £6,500,000 higher than in the corresponding period of last year, but if allowance is made for the imports delayed from 1956, there was actually little change.

Rating of Industry

A White Paper on Local Government Finance (Cmd.209), which was issued last week, deals with proposals for strengthening the rating system in England and Wales. It explains that, at present, industry and freight transported are rated at 25 per cent of their net annual value. From April 1 next, they will be re-rated to 50 per cent of the net annual value. The payments made by the nationalised electricity industry will also be included in the rating system, and the payments on behalf of the nationalised transport industry will be treated as rates.

Iron and Steel

The Iron and Steel Board has stated that, as a result of the Whitsun holiday, British steel production in June fell to a weekly rate of 418,700 tons, compared with 443,200 tons in May and 379,700 tons in June last year. Steel production in the first half of this year amounted to 11,140,000 tons, compared with 10,600,000 tons for the corresponding period of last year, and thus showed an increase of 5·1 per cent. The Board says that, at the beginning of this year, it was estimated that capacity would be available for a production, in favourable circumstances, of 22,400,000 tons of steel in 1957. Output in the second half of the year is always adversely affected by holidays, but as there will be a further increase in capacity by the autumn, there is a reasonable prospect of the year's production exceeding 22,000,000 tons. Pig iron output in the first six months of this year totalled 7,100,000 tons, an increase of 7·2 per cent when compared with production in the first half of last year.

The Board has also pointed out that the greater availability of certain products, especially tinplate and light sections, has led to a marked change in the balance of trade in steel. At present, the excess value of exports over imports is more than sufficient to provide for the import cost of raw materials for steel making, the bulk of these materials being used for producing steel for consumption in the home market. It is estimated that in the first five months of this year the value of exports of steel and some pig iron amounted to £85,500,000, and that in the same period the value of steel imports and raw material imports was £70,200,000. A year earlier these figures were £64,400,000 and £90,500,000 respectively.

A question about sheet and steel strip supplies was put to the Paymaster-General, Mr. Maudling, in the House of Commons on Monday. He was asked what plans the steel industry had for erecting new mills in view of the rising demand for sheet and strip by the exporting industries. In his reply, Mr. Maudling said that plans in hand for the development of existing wide strip mills were designed to provide by 1960 an annual sheet output of over 750,000 tons more than in 1956. Plans for the provision of further sheet and strip capacity after 1960 were under discussion between the Iron and Steel Board and the industry.

Employment and Unemployment

In a report on the employment situation in Great Britain, the Ministry of Labour says that during May there was an increase of 23,000 in the number of people in civil employment. At the end of May, the total was 22,991,000 (15,236,000 men and 7,755,000 women), compared with 23,135,000 a year earlier. The principal changes in May were seasonal ones, occurring mainly in transport and agriculture. Employment in vehicle manufacturing rose, but there was a slight drop in the number of people employed in the engineering industries.

In the manufacturing industries as a whole, the number employed in May was 9,144,000, which indicated a net decline of 1000 during the month. Reference has already been made to the manpower increase in the motor vehicle building industry; it was of the order of 5000 and brought the total number employed to 1,199,000, compared with 1,252,000 in May last year. In the engineering industries, there was a drop of 4000, which brought the total number employed down to 2,777,000, compared with 2,803,000 a year earlier. In other industries and services, the biggest employment change in May was an addition of 12,000 in the group classified as "professional, financial and miscellaneous services." In building and contracting there was another rise of 1000, bringing the number employed to 1,509,000, compared with 1,536,000 a year ago.

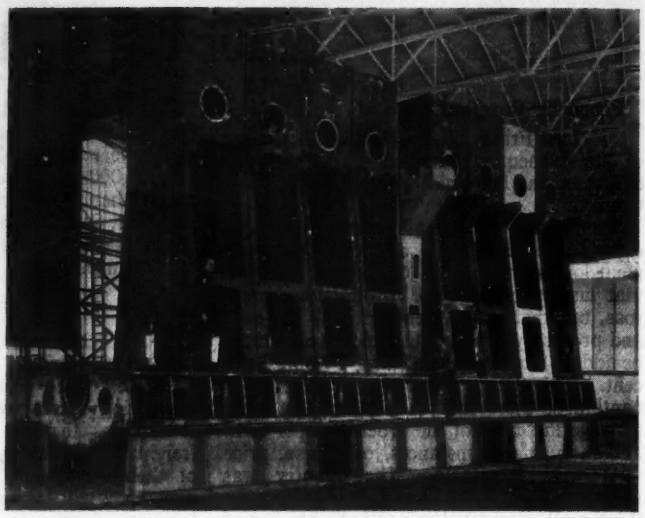
The Ministry says in its report that, in the week ended June 1, there were 1,510,000 workers on overtime in manufacturing establishments. That was 30,000 more than three months ago and 30,000 less than a year ago. In the same week, there were 63,000 on short time in manufacturing establishments, which was 9000 less than a month earlier. On June 17, the report also notes, there were 264,723 people registered as unemployed, compared with 313,472 on May 13. The June figure included 17,741 who were temporarily stopped, and 122,246 who had been out of work for more than eight weeks.

Coal

The Paymaster-General, Mr. Maudling, was called upon to answer many questions about coal production and prices last Monday in Parliament. He was asked, for example, how much the annual production of coal had increased since 1951, to which his reply was that last year's total coal output was virtually identical with that of 1951. Mr. Maudling was then asked if he was aware that "this compares with an increase in wages of 30 per cent and capital investment of over £350 million."

In reply, the Paymaster-General said it was a serious matter that, despite the increased investment in the industry, coal production was virtually stationary between 1951 and 1956. The fact was, he added, that the increase in output per manshift was outweighed by longer holidays, by increased absenteeism and by higher dispute losses, although there was a rise in the total labour force. This year, Mr. Maudling continued, the results which could be obtained from mechanisation had been seen. He hoped that when the present transitional period following upon the abolition of the bonus shift condition was over, there would be seen a resumption of the "very encouraging trend of the first five months of this year."

German Welding Exhibition



During the period June 25 to 28, the Deutscher Verband für Schweisstechnik E.V., Düsseldorf, held its principal meeting at Essen. The occasion also marked the tenth anniversary of the DVS which was formed in 1947 as successor organisation to all technical associations in the field of welding, as well as the sixtieth anniversary of the beginning of co-operative study and research in Germany in this subject with the founding, in 1897, of the "Calciumcarbid-und-Acetylenverein" and the "Deutscher Verein für Acetylen und Carbid." Following upon the DVS meeting, the tenth Congress of the International Institute of Welding began in Essen on July 1 and continued until July 6. In conjunction with these events, the 1957 DVS Special Exhibition "Welding and Cutting" was held at Gruga Park, Essen, from June 23 to July 3.

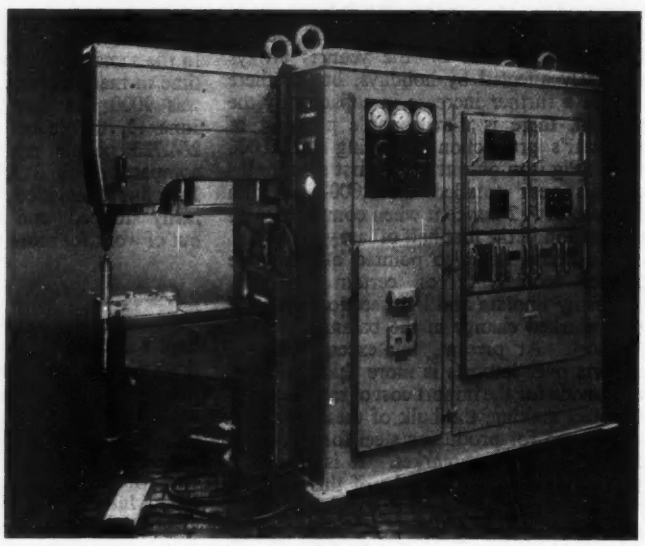
THE 1957 Special Exhibition "Welding and Cutting" of the Deutscher Verband für Schweisstechnik E.V.—the fifth since the war, and the third to take place in Essen—was held from June 23 until July 3 at Gruga Park. The exhibition which had been organised in co-operation with the municipal authorities of Essen, occupied 22,000 square metres, a hall space which was nearly twice that of the previous exhibition in 1954, as well as an open area of 50,000 square metres. In conjunction with this event, the DVS held its 1957 Principal Meeting, marking the tenth anniversary of the Association, with the general theme "Increased rationalisation and productivity through the application of welding." The plenary session was addressed by Professor Dr.-Ing. K. Klöppel, Darmstadt, who spoke to the theme "The Revolutionary Influence of Welding on Technology." The subject was further illustrated by the twenty-six lectures which were given during the working sessions. By invitation of the DVS, the tenth Annual Assembly of the International Institute of Welding was also held in Essen. The assembly which was attended by nearly 1000 participants from twenty-seven countries, was formally opened on July 1 and continued until July 6, the general theme being "The Metallurgy of Welding." It was followed by a number of tours to places of interest in the German Federal Republic, including nearly sixty industrial enterprises in all parts of the country.

In our article we shall describe, without attempting to exhaust the subject, some of the exhibits which we found of particular interest. One hundred and seventy-three industrial firms, as well as the German Federal Railway, took part in the Show, which illustrated the subject of welding and cutting both from the point of view of the available equipment and of actual realisations, such as the 160-ton frame for an eight-cylinder, 10,000 h.p. ships' diesel engine by Ruhrstahl Aktiengesellschaft, Hattingen/Ruhr, which is shown in our title illustration. Information on all technological aspects was given by the DVS Information Stand, while the Teaching and Testing Institutes' Organisation showed a cross-section of its activities, which range from the training of technologists of all grades to research and development, and advisory services.

Much of the equipment could be seen in operation. Among the procedures which were demonstrated may be mentioned a wide range of oxy-acetylene processes shown by B.E.F.A., Beratungsstelle für Autogentechnik, Cologne, while the Federal Railway (D.B.) showed its latest techniques for thermit welding of rails *in situ*. A A special section dealt with aluminium and its alloys.

Knapsack-Griesheim A.G.

A burner of novel conception for the heating of metallic parts, was introduced by Werk Griesheim-Autogen, Frankfurt/Main, of Knapsack-Griesheim A.G. This "spherical-flame" burner cannot blow back under any circumstances as the mixing of oxygen and acetylene is achieved by bringing together jets of the two gases externally. The flame which has a spherical root, is formed a short distance away from the burner, keeping the nozzle cold. Nozzles to fit standard handpieces are supplied.



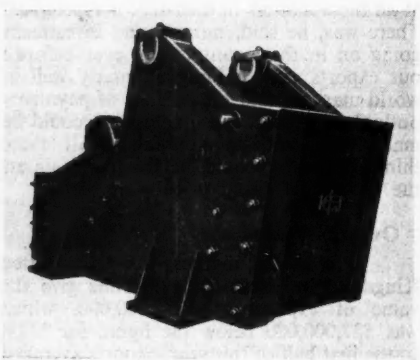
140kVA, three-phase spot welder for light alloys—Siemens-Schuckertwerke

AEG-Elotherm G.m.b.H.

Equipment for the stress-relieving of large objects by induction heating was shown by AEG-Elotherm, G.m.b.H., Remscheid-Hasten. On view was a set-up showing the stress-relieving of a circumferential weld in a 1863mm diameter pipe of 19mm wall thickness, using a 50kW, 2000 c/s motor-generator set. The pipe which is insulated internally and externally by asbestos mats, is wound with a few turns of asbestos insulated cable which is kept at 20 deg. Cent. by internal water cooling. Longitudinal seams can be dealt with in a similar manner, provided the pipe is short enough to allow the coil to be threaded into position. The largest equipment of this kind has a rating of 100kW and is stated to be able to stress-relieve pipes of 3m diameter and 25mm wall thickness. Two generators can be operated in parallel from a single control panel and programme control is available. The largest applications so far were stated to have included the 5m diameter, 35mm thick pipes for the hydro-power station Trausnitz-Rabenleite (all longitudinal and circumferential seams); and reactor vessels, 40m long and 5m in diameter, with wall thicknesses of 50mm. Also shown was induction heating equipment for smaller items such as pipes up to 10m diameter, for which split coils are available. Generators in this range have outputs of 10kW or 50kW, at 10,000 c/s. Normalising at temperatures up to 920 deg. Cent. can also be carried out by this technique, for diameters ranging from about 18mm to 2000mm, and wall thicknesses of 3mm to 37mm.

Gutehoffnungshutte Sterkrade Aktiengesellschaft

In contrast to previous DVS exhibitions, Gutehoffnungshütte on this occasion did not show samples of its electrodes, test welds, &c., but concentrated on examples of welded work-pieces from its own production, such as the jaw crusher frame shown above. This item, weighing 31 tonnes, was welded with 4mm to 6mm diameter electrodes and subsequently stress-relieved.



Completely welded frame for large jaw crusher. Weight 31 tonnes (the complete crusher weighs 71 tonnes)—Gutehoffnungshütte Sterkrade A.G.

Elektro-Bau A.G.

Medium-frequency rotary generator sets for welding purposes were shown by Elecktro-Bau A.G., Linz/Donau. These machines, which are

put on the German market under the name "Schweisshummel," are stated to combine the advantages of d.c. motor-generator sets with those of a.c. welding transformers. A very soft arc is obtained, enabling arc welding to be carried out on black and stainless steel sheets down to 0.75mm thickness or less. Connections are three-phase, but owing to the greater efficiency, the kVA rating is stated to be less than for corresponding d.c. machines. Supply voltage fluctuations have practically no effect. Absence of magnetic splutter of the medium-frequency arc is of advantage in corners. The disadvantages of excitation using slip-rings are avoided by using a polar wheel which is fitted with permanent magnets rotating outside the internally placed stator windings. The arrangement permits a considerable reduction in length and hence a large saving in total space and weight. Regulation is stated to be over a range of 1 : 10 or more. The set is driven by a squirrel-cage induction motor provided with star-delta or series-parallel starter. To the previously available sizes, which were for currents up to 145A and 250A, a version giving up to 400A has now been added (see illustration).

400A, 300 c/s motor-generator welding set for 220/380V, three-phase connection, giving 35/400A in forty-three steps. Weight about 180 kg, full load efficiency 65 per cent—Elektro-Bau A.G.

Adolf Messer G.m.b.H.

An oxy-acetylene burner with economy device was shown by Adolf Messer G.m.b.H., Frankfurt/Main. By releasing a lever fitted to the handle, the burner flame is reduced to minimum size during periods of non-use. On pressing the lever, the flame is restored to its original adjustment without the need to alter the valve settings. By means of a sliding button, the lever can be clamped in the "on" position.

From a large range of equipment shown by this firm may be singled out the "Model R" flame-gouging machine for the cleaning up of slabs prior to rolling. The version illustrated was fitted with four burners, each consuming 300 cubic metres gouging oxygen, 20 cubic metres heating oxygen, and 40 cubic metres gas per hour, and capable of gouging a width of 600mm, 10mm deep per cut. All burners are water cooled, and provision is made for the water cooling of the gas pipes and arm of the machine, if hot gouging is to be carried out, as this involves slab temperatures of around 1000 deg. Cent. For gouging in the cold, speeds of 3m to 18m per minute can be achieved, depending on the depth of cut. The machine can be set by means of stops to carry out a complete cycle automatically, including pre-heating, gouging, and quick-return stroke at six times the forward speed. The U.K. agent is Oxhycarbon Company, Ltd., 299-305, Morland Road, Croydon, Surrey.

Siemens-Schuckertwerke

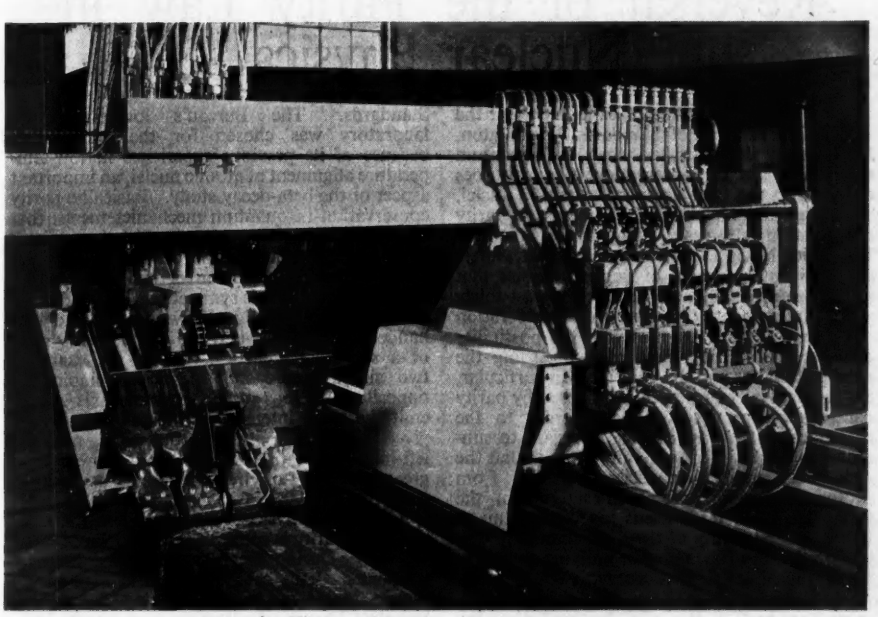
Shown in public for the first time, the "Model WP 713 kg/140/1600" high duty spot-welding machine by Siemens-Schuckertwerke Aktiengesellschaft, Berlin and Erlangen, is stated to be capable of welding light alloys according to the new U.S.A. specification MIL-W-6860 (2mm plus 2·5mm sheets), or with less stringent strength requirements 4mm plus 4mm of light alloy. The machine illustrated is continuously rated at 140kVA, and built for 380V, three-phase connection. The maximum welding current is 80kA, length of the arm 1600mm, and maximum welding force, 2 tonnes. Designed specially for the spot welding of light alloys, the machine is equipped with "DTJ20" ignition control for current and pressure programming. Applications include the construction of aircraft, vehicles, and rolling stock.

Fried. Krupp

A wide range of products from current production was shown by Fried. Krupp which was represented by Fried. Krupp Maschinenfabriken, Essen (locomotives and heavy engineering, chemical equipment, electrical engineering, and light engineering), Fried. Krupp Maschinen-und-Stahlbau, Rheinhausen, and Wipla Dental-Werkstätten, Essen. Some of the largest exhibits were shown by this firm, including an 80 cubic metre welded pressure vessel for the chemical industry, which had a diameter of 4m, a height of 8m, and was designed for a working pressure of 3 atmospheres gauge at 100 deg. Cent. It was constructed of 16mm thick clad plate, the inside consisting of stainless steel ("Niroplat V2A Extra"). Also shown were welded electrical locomotive frames, including the 15-ton frame of an "E50" locomotive, the heaviest locomotive of the German Federal Railway. The frame is over 18m long by 3m wide, and consists of St. 34 plate, and Gs. 52.1 steel castings. The welded frame of a three-axle bogie for this locomotive, also built by Krupp, was shown among the Federal Railway exhibits.

Deutsche Bundesbahn

Of the large array of welding applications displayed, the demonstration of the production of continuous track by thermit welding has already been mentioned. Equipment shown included that used for producing the moulds, and a petrol-driven grinding machine for finishing the welds. Designs for the reconstruction of Essen main station, include a welded single-track railway bridge of novel conception, a section of which could be seen in the exhibition. The bridge comprises a deck formed principally by a box section which rests on end supports and three intermediate columns, forming four continuous spans.



Flame gouging machine—Adolf Messer G.m.b.H.

Peltier Refrigerator

Although the Peltier effect was discovered in 1834, it was not until 1928 that Wall succeeded in maintaining a junction of two metals below the ambient temperature by means of the passage of a current. The magnitude of the Peltier effect—the change in temperature due to the passage of a current through a thermo-junction—can be expressed in terms of the equation

$$T_1/T_2=\sqrt{1+\theta^2}, \text{ where } \theta=\frac{e_p-e_n}{\sqrt{\rho_p\lambda_p}+\sqrt{\rho_n\lambda_n}}\sqrt{T},$$

e being the thermo-e.m.f. against a standard metal, ρ and λ being respectively the electric resistance and the thermal conductivity, while T_1, T_2, and T are the absolute temperatures of the hot and cold junctions, and the mean absolute temperature. With modern semi-conductors, values of T_1/T_2 of 1·1 have been reached, giving a lowering of the temperature by about 30 deg. Cent. A small refrigerator based on the Peltier principle was shown by Les Applications Electroniques, 30, rue des Alouettes, Paris 19e, at the recent Salon de la Physique.* The apparatus consists of rings of bismuth telluride Bi_2Te_3 embedded in plastic, alternately of "n" and "p" type. The eight cold junctions are formed at the centre by joining the discs with inserted short lengths of copper tube, while the hot junctions are at the periphery and are water-cooled. To assist the water-cooling, the outside copper rings are finned. A current of 25A and 1·5V can be sent through the assembly and results in the rapid formation of ice in the central container.

Petrochemical Plant at Cologne

A large petrochemical installation is to be erected in Cologne by Esso A.G., Hamburg, at a cost of some DM.60,000,000. Production is to commence in 1959 in conjunction with the Cologne Esso refinery, which is at present under construction. The works will produce gaseous olefines, using a high temperature process which in Germany has not yet been employed on a large industrial scale. Output is to be distributed to the chemical industry, in part by a pipeline, and will be used for the manufacture of synthetic fibres, plastics, soaps, solvents, synthetic rubber, and resins.

Sea Drilling Platform

An order for the construction of a mobile drilling platform for marine drilling in the open sea off Qatar, in the Persian Gulf, has been placed in The Hague by N. V. de Bataafsche Petroleum Maatschappij of the Royal Dutch/Shell Group. The platform, which will replace the one wrecked off Qatar six months ago, will be built by N.V. Werf Gusto, of Schiedam. It should be ready by the end of next year, when it will be towed out to the Persian Gulf. The original mobile platform, which had already been used to drill two wells off Qatar, was damaged beyond repair during a sudden gale on the night of December 27, 1956.

* The Engineer, June 14, page 924.

The American Scene

BY OUR AMERICAN EDITOR

Growing Production of Transistors

Just when the first major British works for the production of transistors and similar semiconductor devices was announced by Mullards, several American producers of these components also embarked upon large-scale works expansions to cope with the recent unexpected demand. In the United States, the growth of the transistor—after some initial hesitancy—has been truly explosive. Its discovery was announced by the Bell Telephone Laboratories in 1948. Four years later, commercial production still was negligible. In 1955, however, 3,600,000 units, worth over 12,000,000 dollars, were sold. In 1956, sales tripled, to 12,800,000 units, while the dollar volume, despite substantial price cutting, spurted to 37,000,000 dollars. In the first quarter of the current year, the American industry sold over 5,000,000 units, compared to 1,900,000 units, in the like 1956 period. Nor is this all. The transistor is only one member of the whole family of semiconductors. Besides transistors, semiconductors now include diodes and rectifiers, and many American producers make all three. Such tempting prospects naturally have lured a large number of firms into semiconductors. By the latest count, at least forty had entered the field. The devices which have caused all this stir perform much the same functions as those of their predecessors, the vacuum valves, i.e. they control and direct electrical currents in specific, predictable ways. While vacuum valves have been performing these tasks for a half-century, semiconductors enjoy some impressive advantages. First, of course, is the matter of size. A transistor smaller than a pea may be an effective substitute for a vacuum valve 8in tall. Equally important is the ruggedness of the transistor. It need not be enclosed in a fragile envelope which has been evacuated or filled with gas. To the military, particularly, this is a vast improvement. Furthermore, transistors will function on electrical charges which would not suffice to warm up a vacuum valve. By the same token, the heat generated by vacuum valves in operation virtually is eliminated by employing transistors. Finally, the latter have a useful life at least ten times as long as vacuum valves.

The transistor, then, clearly represents a major advance in electronics. However, it has several significant drawbacks. For one thing, it cannot yet be used in many places where the vacuum valve functions with ease. It cannot handle large voltages; except experimentally, it cannot deal with the comparatively high frequencies required by television sets; neither can it quite match the vacuum valve's indifference to heat—self-generated or otherwise—while in operation. Furthermore, on the average the transistor if far more costly. Hence its market penetration has been limited to areas where price is secondary to compactness, strength or low current demand. The first major commercial application for transistors in America, therefore, was in hearing aids. Other uses now include car and portable radios, telephone switching systems, computers, and guided missiles. These present limitations, however, are neither inflexible nor permanent. In fact, the performance of transistors continually is being improved. Thus, with respect to the heat barrier, the industry already has scored a major improvement. In 1954, Texas Instruments perfected transistors made from silicon rather than germanium metal, and the change virtually doubled heat resistance. By the end of 1956, the company was making transistors which would operate at temperatures up to 250 deg. Fah.—nearly 150 deg. more than germanium can stand. According to R.C.A. experimental units are now functioning at temperatures several hundred degrees hotter still. As for higher frequencies, General Electric, among others, announced in April that it had developed three new transistors which are expected to have applications in television and radar, which demand frequencies of 45 to 60 Mc/s. And even in the matter of price, the industry is making progress. General Electric predicts that the crossover point between the prices of transistors and valves will be reached by 1962. At present, however, very few transistors can compete pricewise with their equivalent vacuum valves. A glance at the technological state of the industry explains why. To begin with, the basic raw materials from which transistors are made—germanium or silicon metal—must first be refined to a state of purity perhaps unparalleled in any other industrial process. The next step is somewhat paradoxical. In order to achieve precisely the right degree of resistance to electricity, the semi-conductor material is "doped" or carefully mixed with impurities. Finally, the molecular structure of the metal must be rearranged. To that end, the superpure, carefully doped ingot is remelted and grown as a single crystal. The final product, roughly the size of a plum, then is ready to be sliced down by ultrasonic cutting tools or tiny diamond saws into the hearts of several thousand transistors.

Only after this elaborate raw material processing has been completed does the actual assembly of a transistor begin. The techniques vary widely here, but in one method the sliced bits of germanium or silicon are further shaped by chemical etching; dots of indium are fused to each side of it; and wires are soldered to each of the indium dots. A third wire then is attached, and when the transistor is put in its tiny container, it is complete. Great care, of course, is taken to preserve the purity of the transistor; a microscopic drop of moisture can be ruinous. This assembly process is a painful one to witness—the tolerances required are extremely close, and the operations must be performed by hand. As a consequence, the typical transistor factory consists of rows of girls in white smocks, seated at long tables in a special dehumidified room. The delicacy and difficulty of their tasks may be judged by the fact that on some jobs rest periods are scheduled every twenty minutes. Naturally enough, labour costs are high—upwards of 35 per cent of total costs, according to one firm. Partly because so much of the work is done by hand, and partly because there are still mysteries in transistor technology, there are many rejects. A yield of usable transistors amounting to 75 per cent of the total manufactured is considered exceptional; the average runs around 50 per cent, and pilot production often brings in 20 per cent or less. Some rejects, it is true, can be salvaged; General Electric, among others, stores those which perform within certain ranges against the day when a use for them might appear. Nonetheless, rejects are one of the serious technical headaches which now afflict the industry. Already competition among American transistor makers themselves is growing keener. Recently price-cutting in germanium transistors has become considerable, owing in part to slumping sales of portable radios. The stiffening competition within the transistor trade, its intricate technology, the inevitable advance of semiconductor science and the heavy research costs accompanying it, all are likely to exact their toll. In the face of such barriers, it seems clear that only the strong, the agile and the well-managed concerns will flourish.

Reversal of the Parity Law in Nuclear Physics

RECENT low-temperature experiments at the National Bureau of Standards, Washington, D.C., have demonstrated that the quantum mechanical law of conservation of parity does not hold in the beta decay of cobalt-60 nuclei. This result, together with experiments on parity conservation in μ-meson decay at the Columbia University Nevis Cyclotron Laboratories, alters a fundamental concept of nuclear physics that has been universally accepted for the past thirty years. It thus opens the way for a reconsideration of current physical theories with the possibility of new, far-reaching discoveries regarding the nature of matter and the universe. In particular, the removal of the restrictions imposed by parity conservation promises to bring order to the theoretical chaos now existing in regard to sub-atomic particles. It is generally believed that the new "elementary" particles obtained from proton accelerators are manifestations of the forces that bind the nucleus together. Thus, a better understanding of these particles may well lead to a more fundamental, unifying theory of the nature of matter and energy.

The present beta-decay experiments were carried out by C. S. Wu, of Columbia University, and members of the National Bureau of Standards. The Bureau's low-temperature laboratory was chosen for the experiments because of its previous experience in low-temperature alignment of atomic nuclei, an important aspect of the beta-decay study. Basically, parity conservation in quantum mechanics means that two physical systems, one of which is a mirror image of the other, must behave in identical fashion except for the mirror image effect. In other words, nature is symmetrical and makes no fundamental distinction between right and left-handed rotations or between the opposite sides of a sub-atomic particle. Thus, for example, two similar radioactive particles spinning in opposite directions about the same axis should emit the same intensity of radioactivity in any given direction. Neither the right nor the left-handed rotation should be favoured by a greater intensity of emission as long as parity is conserved.

Since 1925 physicists have accepted the principle that parity is conserved in all kinds of interactions. During the past few years, however phenomena have been described in high-energy physics that could not be explained by existing theories. Large accelerators such as the cosmotron and bevatron have been producing a

Fig. 1—Outer Dewar flasks being placed on glass vacuum chamber containing a sample of radioactive cobalt-60 in beta decay experiment

variety of sub-atomic particles whose behaviour has defied systematic analysis. One such particle is the K meson, a short-lived particle which the proton beam ejects from atomic nuclei. Although K mesons are alike in all significant ways, some of them decay into three π-mesons, while others decay into only two π-mesons. Mathematically, this inconsistent behaviour led to the suspicion that an explanation might be found in a violation of the principle of conservation of parity.

In the summer of 1956, T. D. Lee, of Columbia University, and C. N. Yang, of the Institute for Advanced Study at Princeton, made a survey of experimental information on the question of parity. They concluded that the evidence then existing neither supported nor refuted parity conservation in the so-called "weak interactions," such as emission of a beta particle or K-meson decay. They also proposed a number of experiments on beta decays and hyperon and meson decays that would provide the necessary evidence for or against parity conservation in weak interactions. One of the proposed experiments involved measuring the directional intensity of beta radiation from oriented cobalt-60 nuclei. At the suggestion of Professor Wu, of Columbia, arrangements were made to carry out this experiment in the Bureau's low-temperature laboratory. The polarisation of the nuclei was achieved by cooling a paramagnetic crystal containing cobalt-60 to within 0·01 deg. Cent. of absolute zero, and subjecting it to a magnetic field. At this temperature the effects of thermal agitation are so small that atomic nuclei can line up in a given direction within the crystal lattice when a magnetic field is applied. The magnetic polarity of the nucleus is determined by its direction of spin, and, under the influence of a magnetic field, most of the cobalt-60 nuclei align themselves so that their spin axes are parallel to the field. As cobalt-60 is radioactive, its nuclei continuously emit beta and gamma-rays. If parity is conserved in such interactions, then the intensity of the beta emission should be the same in either direction along the axis of spin. This, of course, was the critical question in the cobalt-60 experiments. It was resolved by measuring the intensity of beta emission in both these directions, i.e. along and against the field direction.

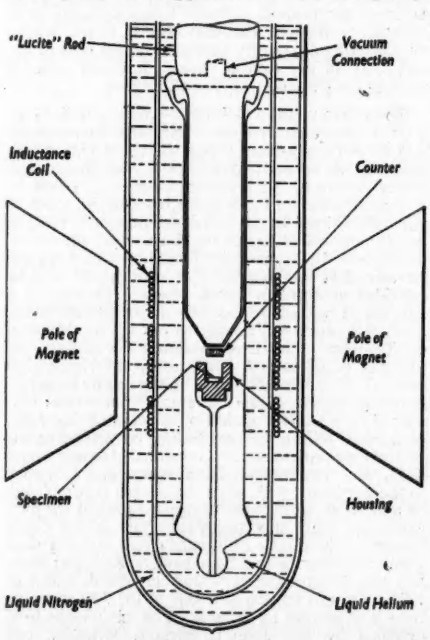


Fig. 2—Schematic diagram of evacuated glass vessel apparatus used at the N.B.S. in the study of beta decay of polarised cobalt-60 nuclei

The cobalt-60 was placed in a 0·002in thick surface layer of a single crystal of cerium magnesium nitrate. As illustrated in Fig. 1, the crystal was placed in an evacuated flask which, in turn, was immersed in liquid helium within a Dewar flask surrounded by liquid nitrogen. An inductance coil on the surface of the inner flask was used to measure the temperature of the crystal in terms of its magnetic susceptibility. A major experimental problem was the position of a radiation counter within the evacuated flask for the detection of beta particles. As shown in Fig. 2, this problem was solved by placing a thin anthracene crystal inside the chamber to serve as a scintillation counter. The anthracene crystal was situated about 2cm above the cobalt-60 source. The scintillations caused by beta particles striking the crystal were transmitted through a glass window and a 4ft "Lucite" tube acting as a light pipe to a photo-multiplier at the top of the flask. The resulting pulses were counted on a ten-channel pulse-height analyser.

In addition to the beta counter within the vacuum chamber, two sodium iodide gamma scintillation counters were used externally to measure the directional intensity of the more penetrating gamma radiation. In this way the investigators were able to determine the degree of polarisation of the cobalt-60 nuclei. The two gamma counters were biased to accept only the pulses from the photo-peaks in order to discriminate against pulses from Compton scattering. The cooling to the low-temperature necessary for nuclear alignment was accomplished by the process of adiabatic demagnetisation using a magnetic field of about 23,000 oersteds. The large magnet used in these experiments is illustrated in Fig. 3. This process involved the successive magnetisation and demagnetisation of the paramagnetic salt, cerium magnesium nitrate, which supported the cobalt-60 specimen. The heat produced by magnetisation was removed by the boiling off of liquid helium in the surrounding dewar. The specimen was then thermally isolated and upon demagnetisation the temperature fell to about 0·003 deg. Kelvin.

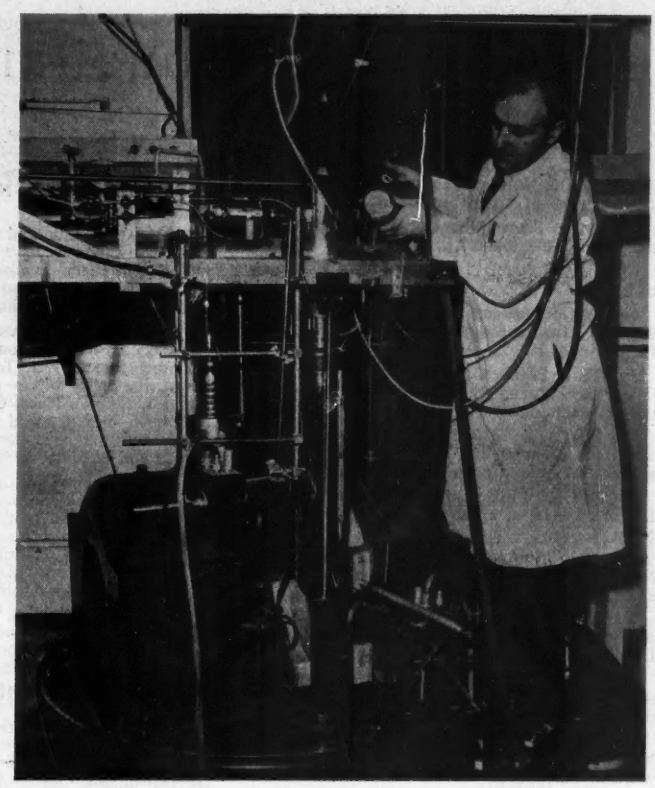


Fig. 3—Liquid nitrogen being added to outer flask of cryostat containing a sample of cobalt-60, with cooling magnet surrounding the flask bottom

A vertical solenoid was then raised around the lower end of the outer dewar to provide a magnetic field for polarisation of the cobalt-60 nuclei. After the beta emission had been measured for this condition, the direction of the magnetic field was reversed, and the beta emission again measured for nuclei polarised in the opposite direction. It was found that the emission of beta particles was greater in the direction opposite to that of the nuclear spin. Thus, a spinning cobalt-60 nucleus has a beta emission distribution that is not the same as that of its mirror image. This result unequivocally demonstrates that parity is not conserved in the emission of beta particles by cobalt-60. According to the theoretical studies of Professors Lee and Yang, the present experiment indicates not only that the conservation of parity is violated in beta decay, but also that invariance under charge conjugation is violated. This can be interpreted to mean that when the algebraic signs of all electric charges in a physical system are changed, the physical behaviour of the system may not always remain unaltered. More recently, Lee and Yang have developed a new theory for the neutrino. Further low-temperature studies of beta decay are proceeding at the Bureau and it is hoped that the invariance of time reversal—changing the algebraic sign of time in time-space equations—can be decided.

CHROMIUM-51 AS A GAMMA-RAY SOURCE.—We have learned from the Battelle Institute, Ltd, 24, Ryder Street, St. James's, London, S.W.1, that an unusual use has been found for the very pure chromium now available through a Battelle-developed process. Professor William G. Myers of The Ohio State University utilised radiated crystals of the metal supplied by Battelle as a source of gamma-rays in radiation therapy. His study shows that the crystals, as chromium-51, show promise both as removable and permanent gamma-ray sources. Because of its 28-day half life, Professor Myers reports that chromium-51 may prove to be superior to gold-198, radon-222, and other shorter-lived radioisotopes for permanent implantations.

Personal and Business

Appointments

MR. G. K. WRIGHT has been appointed export sales manager of Rotary Hoes, Ltd.

MR. JAMES SMITH MOFFAT has been appointed a director of Weldall and Assembly, Ltd.

MR. E. W. JONES has been appointed sales manager of Isotope Developments, Ltd., Aldermaston.

MR. P. GOUDIME has been elected president of the Scientific Instrument Manufacturers' Association for the year 1957–58.

MR. K. S. PEACOCK has been elected chairman of Guest Keen Iron and Steel Company, Ltd., following the retirement of Mr. J. H. Jolly.

THE BUTTERLEY COMPANY, Ltd., has announced that Mr. H. R. Newman and Mr. R. Hermon have been appointed joint managing directors.

AMBER OILS, Ltd., has announced that Mr. V. E. Baker has been appointed commercial director and Mr. E. G. Reynolds, works director.

MR. J. W. SIMPSON, A.M.I.E.E., has been appointed chief electrical engineer to the Coniston Company, engineering consultants, Wimbledon.

MR. P. F. EISLER has been appointed export sales manager of David Brown Industries, Ltd., Tractor Division, Meltham, near Huddersfield.

THE BRITISH TRANSPORT COMMISSION has announced that Mr. L. J. Hamblin has been appointed secretary of the British Railways Productivity Council.

MR. J. H. SEPHTON has been appointed London branch manager of Alfred Herbert, Ltd., in succession to Mr. William Core, who is now sales director.

WILLIAM MILLS, Ltd., has announced the appointment of Mr. Andrew Blyth as managing director in succession to Mr. J. F. Paige, who is to retire on July 31.

THE SPERRY GYROSCOPE COMPANY, Ltd., has announced the appointments of three new directors. They are Mr. C. J. Bridge, Mr. H. B. Sedgfield, A.M.I.E.E., and Mr. S. E. Spicer.

MR. H. W. FULTON has been appointed an executive director of the North British Locomotive Company, Ltd., Glasgow. He will be in control of the manufacture of all North British/M.A.N. diesel engines.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., has announced the appointments of three branch managers of sales offices in Lancashire. Mr. C. R. Bryant has been appointed manager of the Manchester office; Mr. F. L. Johnson, the Blackburn office, and Mr. T. Noblett, the Preston office.

Business Announcements

MR. J. P. CRANMER, M.I.E.E., engineer, Midlands area, of the British Thomson-Houston Company, Ltd., has retired after forty-five years' service.

THE GLACIER METAL COMPANY, Ltd., states that it has opened a new three-storey warehouse and office block opposite its main London factory at Alperton.

ACROW (ENGINEERS), Ltd., South Wharf, Paddington, London, W.2, states that it has been appointed sole agent in the United Kingdom for the Demag electric hoists and cranes.

MR. F. A. BENGER, chief of motive power and rolling stock for the Canadian Pacific Railway, is to retire at the end of July, having served the company for more than forty-six years.

WICKMAN, Ltd., has been appointed sole world selling agent for the Eldair range of mechanical and hydraulic press brakes and plate shears manufactured by Weldall and Assembly, Ltd., Stourbridge.

MR. J. H. RIVERS, chief designer and technical director of Craven Brothers (Manchester), Ltd., has retired from active service with the company, but has been engaged as its engineering consultant and adviser.

BUCKLEY AND TAYLOR, Ltd., Oldham, states that it has appointed John Turner and Co., 25, Collingwood Street, Newcastle upon Tyne, as agent for Northumberland, Durham, Cumberland and Westmorland.

AMBER OILS, Ltd., states that world distribution of its pressurised dispenser products, "Aerozene" penetrating oil and spring lubricants, "Blink" invisible metal protector, and "Rusolvent" easing fluid, has been taken over by Slip Products and Engineering Company, Ltd., 34, Great St. Helen's, London, E.C.3.

LEOPOLD LAZARUS, Ltd., City Wall House, 79–83, Chiswell Street, Finsbury Square, London, E.C.1, states that it has been appointed sole representatives in Great Britain of the National Steel Corporation of Pittsburg, U.S.A.

MILLSPAUGH, Ltd., and GEORGE WIMPEY AND CO., Ltd., state that they have decided to form a jointly owned subsidiary company, Millspaugh/Wimpey, Ltd., for the designing, supply and building of complete pulp and paper-making plants.

WILLIAM H. CAPPER AND CO., Ltd., states that it has opened a new London office, Mayfair House, 9, Hertford Street, W.1, from which its sales and advertising policy will be directed. The premises at 1 and 3, Elliott's Place, Colebrooke Row, London, N.1, have been retained as the site of its London works and the headquarters of the Capper Pipe Service and Welding Company, Ltd.

THE PULSOMETER ENGINEERING COMPANY, Ltd., Reading, states that it has acquired the whole of the issued share capital of the Self-Priming Pump and Engineering Company, Ltd., Trading Estate, Slough. Mr. F. B. Duncan, chairman, and Mr. J. S. Woodrow, managing director of the Pulsometer Engineering Company, Ltd., have joined the board of directors of the Self-Priming Pump and Engineering Company, Ltd.

Contracts

THE POWER-GAS CORPORATION, Ltd., Stockton-on-Tees, in association with licensees in Germany, Didier-Werke A.G., Essen, has received an order for two units of Segas plant, each of 30,000 cubic metres per day for the gasworks at Rostock, Eastern Germany.

TALBOT STEAD TUBE COMPANY, Ltd., Walsall, has received a contract, worth nearly £750,000, from C. A. Parsons and Co., Ltd. (a member of the Nuclear Power Plant Company, Ltd.), for specialised atomic reactor components for the Bradwell nuclear power station in Essex.

METROPOLITAN-VICKERS SOUTH AFRICA (PTY.) Ltd., has received from South African Railways an order for 135 electric locomotives worth over £7,600,000. Each locomotive has four axles, is rated at 2000 h.p., and weighs 80 tons. The electrical equipment will be made at the Metropolitan-Vickers works at Sheffield and Trafford Park, and the mechanical parts will be made and erection of the locomotives carried out at the Stockton works of Metropolitan-Vickers-Beyer, Peacock, Ltd. The first locomotive is to be delivered within twenty months.

Miscellanea

PORTABLE PROCESS-TIMER.—A portable process timer, known as the T.D. 50, has been placed on the market by Industrial Timing Instruments, Ltd., 25, Holborn Viaduct, London, E.C.1. Three separate dials register minutes, seconds and tenths of seconds.

FILMS AND MODELS OF CIVIL ENGINEERING.—A number of civil engineering contracting firms have films and models of civil engineering which are available for exhibition. The Federation of Civil Engineering Contractors has compiled lists of these films and models, and copies of the lists can be obtained from the head office of the Federation at Romney House, Tufton Street, Westminster, S.W.1.

DYNAMIC BALANCING EQUIPMENT.—A new range of electronic balancing machines for electrical rotors, pump shafts, and crankshafts, is announced by C. F. R. Giesler, Ltd., Small Hall, River Place, Essex Road, Islington, London, N.1. It is claimed that a deflection of 0·000025in can be detected, and that the accuracy can be expressed approximately as 0·00002 of the weight of the test rotor.

LOADING FACILITIES AT KUWAIT.—The Kuwait Oil Company, Ltd., and the British Petroleum Company, Ltd., announce that four submarine pipelines to form two submarine berths are to be added to the tanker loading facilities at Mina-al-Ahmadi. Each berth will have a 24in and a 12in line, while on land a 32in gravity line is under construction. These projects will increase the crude oil loading capacity to about 75,000,000 tons per year.

TELEVISION FOR TRAFFIC CONTROL.—Britain's first permanent television installation for traffic control is to be set up in the Market Square at Durham. The constable controlling the traffic lights on the bridges, from his police box in the square, cannot see the number of vehicles waiting, so he must estimate the time needed to clear each line of traffic between the square and the bridges. Hence the television cameras. This new method of traffic control was tried out successfully in Durham in August, 1956, and is now to be installed permanently.

LUBRICATION OF FREE-PISTON ENGINES.—Development and service experience with the free-piston gas generator has led to the introduction of a special lubricant. Up to 1950, the G.S. 34 units supplied by S.I.G.M.A. (Societe Industrielle Generale de Mechanique Appliquee) had used steam cylinder oil for cylinder lubrication, and both wear and cleanliness of cylinder and moving parts were unsatisfactory. Similar problems were encountered by General Motors in the development of European generators; in this case, surface finishes were brought into line with established diesel practice, and improved cooling reduced valve deposits and valve leakage. Various lubricants were subjected to trial on S.I.G.M.A. G.S. 34 generators, and the final product "Shell" free-piston engine oil is now in use on practically all S.I.G.M.A. units except those operated by the French Navy.

"PERSEUS" INSURANCE COMPUTER FOR SOUTH AFRICA.—The South African Mutual Life Assurance Society is to install a Ferranti "Perseus" electronic data-processing system at Mutualpark, Pinelands, Cape Town, at a cost of nearly £250,000. It is due for delivery in 1958 and will be used for maintaining the complete policy records of the Society. Ferranti, Ltd., has conducted a programming course at Mutualpark. The installation will employ about fifty people. Input data will be on Powers-Samas sixty-five column punched cards. The information will be fed into "Perseus" through a Powers-Samas card reader. The output will be on to magnetic tape which may be kept as the permanent file and the contents printed for the issue of premium notices, commission statements or the compilation of normal office records. The printing will be done by a Powers-Samas magnetic tape printer which operates at a speed of 42,000 characters per minute with a repertoire of fifty different characters.

WORLD MOTOR MANUFACTURE.—The Monthly Statistical Review of the Society of Motor Manufacturers and Traders, Ltd., for June, records the output figures for the main producing countries in the first three months of 1957. The principal producers of cars were the U.S.A., 1·78 million; Western Germany and France, 0·178 million. The largest totals of production belong to the same countries, but in commercial vehicle production this country is second to the U.S.A., building 67,022. Great Britain was last year the second largest exporter of both cars and commercial vehicles, 317,992 cars, against Western Germany's 421,379, and 146,044 commercial vehicles, against 197,547 from U.S.A. It is interesting to note that while these totals are not greatly dissimilar, the exports to each continent of these countries are in all cases widely different, the nearest approach being car imports in America; Western Germany 99,000, Great Britain 69,000. Of this country's exports, 55 per cent of the cars and 58 per cent of the commercial vehicles went to the Commonwealth and Empire.

ROAD IMPROVEMENT SCHEMES.—Work is expected to start immediately on the £600,000 improvement scheme for an 8-mile stretch of the Great North Road (A.1) between Woolpack Cross Roads and Water Newton, in Huntingdonshire. Work is already in hand on the 5-mile stretch to the south of Woolpack Cross Roads as far as Alconbury Hill, so that a continuous length of 13 miles in all will be improved. Throughout this length of road there will be twin 24ft carriageways. A roundabout will be provided at Norman Cross, where A.15 joins A.1, and the village of Stilton will be by-passed to the east. The work will be carried out for the Ministry of Transport and Civil Aviation by Robert M. Douglas (Contractors), Ltd., under the supervision of Mr. T. H. Longstaff, M.I.C.E., the county surveyor, Huntingdonshire County Council. Work has also started on a further section of the central ring road, planned to relieve the very serious congestion in the central area of Leicester. It is estimated to cost about £116,700. Traffic from Birmingham and Coventry to the north-east will, when the section is completed, be able to avoid the most congested part of the city, where five main shopping streets join at the Clock Tower. It is intended ultimately that the ring road should provide for two carriageways, each 30ft wide, and two 15ft footpaths, within an overall width of 112ft. On this section only one of the 30ft carriageways is at present to be built. The scheme has been designed by Mr. John L. Beckett, M.I.C.E., city surveyor and planning officer, and will be carried out under his supervision. The contractors are Messrs. Chapman and Dowd.

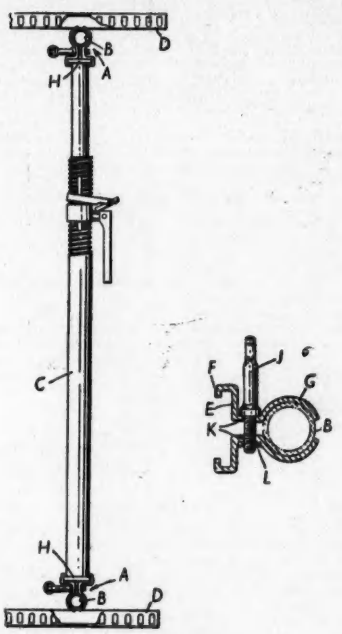
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

CIVIL ENGINEERING

778,387. January 5, 1954.—CLAMPING COUPLINGS, Rapid Metal Developments, Ltd., 209, Walsall Road, Perry Barr, Birmingham, 22b. (*Inventor: Alfred Sutcliffe.*)

The invention relates to a clamping coupling which is primarily, although not exclusively, intended for use with a prop or strut in civil engineering operations for propping a metal shuttering construction or in strutting lining in a trench construction. As will be seen in the drawing, clamping couplings generally indicated at *A* are employed in conjunction with props *B* and a telescopic strut *C* for strutting trench or culvert linings *D*. Each coupling comprises a pair of clamping members *E*, each having at its respective ends dissimilar jaws *F* and *G*, these jaws combining to form two dissimilar end clamps, each adapted to receive an end *H* of the telescopic strut *C* and a prop *B* which is to be pressed against the linings *D* by the strut. A screw threaded clamping bolt *J* is received in registering holes *K* in the clamping members *E* and when



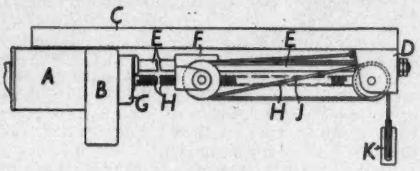
No. 778,387

tightened against one of the members tightens the jaws into tight engagement with the prop and the end of the strut. Each clamping member is made of a pressed steel strip constructed with an inwardly turned hooked jaw *F*, an arcuate jaw *G* and an intermediate flat strap. The hole *K* in one of the members is plain and the other has a nut *L* welded to it, which is aligned with its hole to obtain a reinforced nut for the bolt. The telescopic strut *C* is described in Specification No. 746,083, and it will be appreciated that the clamping coupling *A* can be simply and easily placed in position by slackening the bolt *J* and engaging the jaws *F* and *G* respectively with the ends *H* of the strut *C* and with the prop *B*. On tightening the bolt, as by inserting a tommy bar in a hole provided in the end of the bolt, both clamping members are drawn inwardly and simultaneously both clamps are tightened about the respective parts. When a coupling is used at each end of the strut *C*, as shown in the left-hand view, then by adjusting the strut in an extending sense, the props *B* are held tightly in physical contact with the linings *D*.—*July* 3, 1957.

CRANES AND HOISTS

777,963. July 30, 1954.—HOISTS AND LIFTING OR LOWERING APPARATUS, Campbell and Isherwood, Ltd., Penpoll Works, Hawthorne Road, Bootle, Liverpool, 20; and Robert Rawlinson, 2, Brownmoor Park, Liverpool, 23.

An object of the invention is to provide a robust and yet relatively inexpensive hoist which is of simple construction and is simple in operation. The hoist shown on the drawing comprises an electric motor *A* and reduction gearing located in a casing or gearbox *B*. Supported by the motor and gearbox is a channel section cantilever member *C*, the extremity of which carries a block *D*. Extending between the gearbox and the block is a guide rod *E* which slidably supports a further block *F*, referred to as the movable pulley block. Journalled at its ends in an extension *G* of the gearbox *B* and in the block *D* respectively is a screw *H*, which is threaded through a "nut" located in or attached to the movable pulley block *F*. The screw is rotated by the motor through the gearing in the gearbox. Rotatably supported in the block *D* are two pairs of sheaves, as shown. Similarly, the



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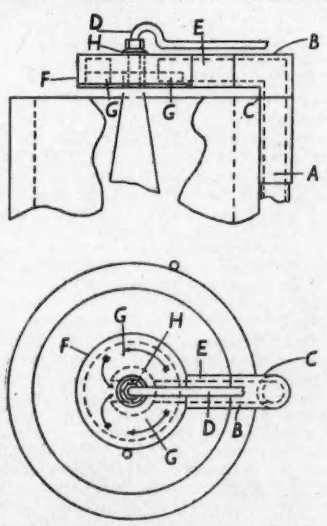
movable pulley block *F* has rotatably supported in it two pairs of sheaves. Reeved between the sheaves of the fixed pulley block and the sheaves of the movable pulley block is the rope or tackle *J*, which has a running end to which is attached the lifting block *K*. In operation, the motor *A* rotates the screw *H* so as to traverse the movable pulley block *F* along its guide rod *E*. This movement serves through the tackle *J* to raise or lower the block *K*. It will be appreciated that any desired velocity ratio and mechanical advantage can be obtained by suitable selection of the number of sheaves incorporated in the pulley blocks *D* and *F*. Furthermore, considerable mechanical advantage is afforded through the screw mechanism *H* by which movement of the block *F* is effected. The member *C* need not, of course, be in the form of a cantilever, and it can be supported at one or both ends on, for example, rollers adapted to run on a rail or rails. Alternatively, the member may be fixed to an overhanging girder along its entire length. A hand-powered device can, of course, be substituted for the motor.—*July* 3, 1957.

BURNERS AND SPRAYERS

778,385. December 28, 1953.—LIQUID FUEL BURNER, Thomas William Shaughnessy, 121, Milling Street, Gateshead-on-Tyne, County Durham.

The device relates to a liquid fuel burner which circulates pressurised and preheated air. The preheated air is brought into contact with fuel oil and atomises and injects the oil into a melting vessel, which serves as the combustion chamber for the air and fuel oil. In the drawing the burner is shown mounted on top of a melting vessel. *A* is a metal sleeve which is attached to the outside of the metal body of the melting vessel. Through this sleeve passes an air pipe *B* having a right angle joint and shoulder, resting on top of the metal sleeve at *C*. The pipe *B* can rotate in the sleeve, the oil fuel pipe *D* moves with the air pipe *B*, and can be connected to it by metal straps. In operation, pressurised air passes from an air compressor to the air pipe *B* and passes via an extension air pipe *E* to an air preheater *F* which is a shallow inverted metal channelled



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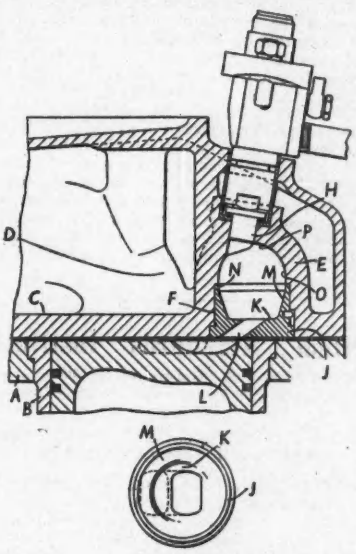
annulus into which fits the extension air pipe *E*. The open end of the channelled annulus is covered by a metal plate, the two to form an internal air passage *G*, by means of which the pressurised air is circulated and thus preheated owing to the preheater being disposed over the hot melting vessel. The air pipe extension *E* fits into an aperture in the outer wall of the annulus, and the air passes into the bore at the centre of the annulus through an aperture in its inner wall. Passing through the channelled annulus the central bore is continued through the metal cover plate. Through this bore passes freely the fuel oil injector tube *H*, which has a shoulder and is seated on top of the annulus. Directional arrows in the lower view show the direction pressurised air takes as it passes to the centre of the preheater and its exit around fuel oil injector tube *H*, which is centrally disposed in the central bores of the annulus and cover plate. The oil fuel feed pipe *D* is connected to the top of the fuel oil injector tube *H*. Preheated, pressurised air meets fuel oil issuing from the bottom of the fuel oil injector tube, atomises it, and injects it into the melting vessel, which is also the combustion chamber. The upper view illustrates a jet of air and oil issuing from the centre of the device. When starting from cold, to gain instant ignition of the air and fuel oil, it is sufficient to thrust into the oil and air stream coming from the centre of the preheating device a glowing red metal bar or tube.—*July* 3, 1957.

INTERNAL COMBUSTION ENGINES

777,970. October 11, 1954.—COMPRESSION IGNITION ENGINES, Ricardo and Co., Engineers (1927), Ltd., 21, Suffolk Street, Pall Mall, London, S.W.1. (*Inventor: George Allen Holt.*)

The invention relates to internal combustion engines of the compression ignition liquid fuel injection type, in which substantially the whole or a substantial proportion of the air charge is forced during each compression stroke through a transfer passage into a combustion pocket of such shape and in such manner that the charge is caused to rotate within the pocket about an axis perpendicular to the axis of the transfer passage, the fuel being injected into the rotary air charge in the pocket, usually in



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a manner such that it is directed towards a part of the circumferential surface of the pocket across which the circumferential portions of the rotating air charge sweep shortly before they reach the mouth of the transfer passage. In the construction shown the engine comprises a cylinder block *A* containing cylinders in the form of liners *B* of which one is shown, the upper ends of the cylinder bores being closed in the usual manner by a cylinder head *C* provided with inlet and exhaust passages indicated generally at *D*. Formed in the cylinder head adjacent to each cylinder bore is a combustion pocket *E* having a generally cylindrical mouth portion *F* and a hemispherical inner end portion *P*, in which is mounted a fuel injection nozzle *H*. Arranged in the mouth portion *F* of the pocket is a hot plug *J*, arranged so that its inner surface is of approximately hemispherical form so as to provide a pocket having an approximately spherical internal contour; it is formed on its inner surface with a flat area *K* of substantial dimensions, through which opens the transfer passage *L* by which the pocket communicates with the cylinder bore, while the part of the interior surface of the plug *J* which surrounds the flat area *K* is of frusto-conical form, as shown at *M* with the flat area at the smaller end of the frustum. The larger end of the frustum runs into a short cylindrical surface area *N* which runs smoothly into a short cylindrical area *O* of the same diameter at the end of the hemispherical end surface *P*. As will be seen, more especially from the lower view, the transfer passage *L* is of roughly rectangular form and its mouth opens through the flat area *K* with its

periphery displaced from the periphery of this flat area. This arrangement renders the exact disposition of the mouth less critical than with a spherical pocket and avoids the necessity for it to be so accurately disposed and formed that the appropriate one of its sides runs smoothly into the inner surface of the pocket. As will be apparent from the drawing, the air charge which during the compression stroke is forced through the transfer passage *L* will have a direction which is tangential to a circle struck from an axis passing through about the centre of volume of the pocket and normal to the plane in which the cross-section of the drawing is taken and so that at the end of the compression stroke the air charge within the pocket will be in a state of general rotation about such axis. A modified construction is also shown in the specification.—*July* 3, 1957.

METALLURGY

777,987. January 26, 1955.—CAST IRON, Metropolitan-Vickers Electrical Company, Ltd., St. Paul's Corner, 1-3, St. Paul's Churchyard, London, E.C.4. (*Inventors: George Arthur Southern and Arthur Phillips.*)

The invention relates to the manufacture of cast iron and particularly grey cast iron. According to the invention, magnesium and cerium are included in cast iron by the addition to the molten cast iron of the products of reacting magnesium metal with a cerium halide, preferably cerium chloride. The resultant cast iron obtained with the process according to the invention has improved mechanical properties and in particular greatly increased tensile strength and resistance to shock. With suitable subsequent heat-treatment(s) greater ductility may also be obtained. In practising the invention it is essential that the magnesium metal and cerium halide be melted together first, the resultant product, preferably after being allowed to solidify, being subsequently added to the molten cast iron. It is believed that with the process according to the invention the melting together of magnesium metal with cerium halide results in a mixture containing magnesium metal with cerium metal and a mixture of magnesium and cerium halides and possibly a double halide. The use of cerium halide with the molten cast iron overcomes the inhibiting effects of trace elements, such, for example, as bismuth, tin and arsenic, in the cast iron. It is at present intended to employ a mixture of equal weights of magnesium and cerium halide. However, other proportions may be used provided that where trace elements are present in the molten iron there is sufficient cerium, either as metal or salt, to overcome the inhibiting effects of trace elements.—*July* 3, 1957.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, *Park Street, London, W.*1.

STEEL PLATES FOR USE IN THE MANUFACTURE OF GALVANISING POTS

No. 2858 : 1957. Price 2s. 6d. This new Standard was prepared at the request of the Hot Dip Galvanizers' Association. It specifies a grade of steel suitable for use in contact with molten zinc in galvanising pots. Such plates are to be not less than ¼in thick, and may be made by the open-hearth or electric process, or by any process agreed between purchaser and manufacturer.

Apart from general requirements, the standard specifies the quality of finished steel and for rolling margins. Among the marking requirements is one which provides for the encircling in white paint of identification numbers or marks.

METHODS OF TESTING PLASTICS

No. 2782 : 1957. Price 5s. This standard is the second part of what will become a series of test methods used by the plastics industry for assessing the quality of its products. (B.S. 2782, Part I, dealt with "Effect of Temperature.") The methods are being prepared with the full collaboration of the British Plastics Federation. Part II specifies tests to be applied to moulding and extrusion compounds, synthetic resins and their solutions, semi-fabricated products, such as sheet, thin film, rod and tube. The tests relate to the electric strength, volume resistivity, surface resistivity, insulation resistance, power factor and permittivity at 50 c/s, power factor and permittivity at 800 to 1600 c/s, and power factor and permittivity at 10 kc/s to 100 Mc/s. For each property requirements are specified for the form of the test specimens and the number to be used, apparatus, procedure and method of reporting. The standard—which is illustrated—contains an alphabetical index. When preparing future editions, attempts will be made to unify allied methods which differ only in arbitrary matters, so that a single method of test will apply to a much wider range of materials than at present.

Launches and Trial Trips

SANDPIPER, open shelter deck cargo ship; built by Henry Robb, Ltd., for the General Steam Navigation Company, Ltd.; length between perpendiculars 215ft, breadth moulded 36ft 6in, depth moulded to upper deck 20ft 6in, deadweight 1000 tons on 12ft 10in mean draught; four holds; bale capacity 70,000 cubic feet; one 15-ton and six 5-ton derricks, electric winches, three 80kW diesel-driven generators; one eight-cylinder British Polar diesel engine, 1280 b.h.p. at 250 r.p.m.; trial speed 12·5 knots. Launch, May 1.

BRITISH COURAGE, oil tanker; built by Hawthorn Leslie (Shipbuilders), Ltd., for B.P. Tanker Company, Ltd.; length overall 680ft, breadth moulded 86ft, depth moulded 48ft, deadweight 32,000 tons; thirty cargo oil compartments, one main cargo pump room; two 600kW, 440V, 60 c/s turbo-alternators, one 150kW diesel-driven alternator, one 75kW steam-driven alternator; one set of double reduction geared turbines, 15,500 normal s.h.p. at 112 propeller r.p.m., but can develop 22,500 s.h.p. at 126 propeller r.p.m., two Babcock and Wilcox selectable superheat boilers provide steam at 850 deg. Fah. Launch, May 13.

SUX. XX., tug; built by Philip and Son, Ltd., for W. H. J. Alexander, Ltd.; length overall 107ft 3in, length between perpendiculars 100ft, breadth moulded 25ft 6in, depth moulded 12ft 8in, displacement 394 tons; Hamworthy 300 tons per hour against 60ft head salvage pump, fire pump 900 gallons of foam per minute; one six-cylinder Ruston and Hornsby diesel engine, 1210 b.h.p. at 375 r.p.m., Hindmarch-Modern Wheel Drive 3 : 1 reduction gear. Trial, May 14.

GRECIAN EMBLEM, closed shelter deck cargo ship; built by the Blythswood Shipbuilding Company, Ltd., for Olinares Compania Naviera S.A., Panama; length 470ft, breadth 63ft 2in, depth 30ft 11in, deadweight 13,800 tons, draught 27ft 6in, trial speed 15½ knots; five cargo holds, one 30-ton, four 10-ton, six 5-ton derricks, electric winches; three 250kW diesel-driven generators; Scott-Doxford opposed-piston diaphragm oil engine, 6200 b.h.p. Launch, May 15.

BOSTON VANGUARD, trawler; built by Vosper, Ltd., for the Saint Andrew's Steam Fishing Company, Ltd.; length overall 126ft 6in, length registered 115ft 6in, breadth moulded 25ft, draught aft 14ft, fish hold 6750 cubic feet; speed 11 knots; one Mirrlees six-cylinder diesel engine, Mark KSCDM6, 675 b.h.p. at 250 r.p.m. Launch, May 20.

DAVID WOOD, trawler; built by John Lewis and Sons, Ltd., for the Minerva Fishing Company, Ltd.; length overall 133ft, breadth 25ft 6in, depth 12ft 9in; fish room 6500 cubic feet, 150 b.h.p. electric trawl winch, 800 fathoms, 2¼in warp; two 20kW diesel-driven generators, one 125kW trawl diesel-driven generator; Widdop Mark G.M.B.7 diesel engine, 650 b.h.p. at 250 r.p.m. Trial, May 24.

WAROONGA, cargo liner; built by Barclay, Curle and Co., Ltd., for the British India Steam Navigation Company, Ltd.; length 520ft, breadth 68ft 3in, depth to shelter deck 42ft 3in, gross tonnage 10,000; speed 20 knots, deadweight 11,500 tons, draught loaded 28ft 1½in; five holds, eighteen derricks, electric winches; four 300kW diesel-driven generators; one set of double reduction geared compound turbines, 10,850 s.h.p., 112 propeller r.p.m., two Babcock and Wilcox water-tube boilers supply steam at 500 lb per square inch and 800 deg. Fah. Launch, May 28.

NORTH EMPRESS, cargo ship; built by the Blythswood Shipbuilding Company, Ltd., for Palamedes Compania Naviera S.A., Panama; length 485ft, breadth 67ft 6in, depth 41ft 10in, deadweight 15,200 tons on closed shelter deck draught of 31ft 0¾in; trial speed 17¼ knots; six holds, one 50-ton, one 25-ton and twelve 10-ton derricks, electric winches, three 300kW diesel-driven generators; Scott-Doxford opposed piston diaphragm oil engine, arranged to burn heavy fuel, 7200 b.h.p. Trial, May 28.

HUNTSVILLE, cargo ship; built by the Burntisland Shipbuilding Company, Ltd., for the Power Steamship Company, Ltd.; length between perpendiculars 450ft 3in, breadth moulded 63ft 10¼in, depth moulded to shelter deck 40ft 5in, draught 27ft 10in, deadweight 12,200 tons; five cargo holds, four 10-ton and six 5-ton derricks, electric deck machinery, three 320kW diesel-driven generators; Hawthorn-Doxford oil engine, six cylinders, 670mm by 2320mm combined stroke, 6600 b.h.p. at 115 r.p.m. Launch, May 29.

THESSALY, cargo ship; built by Harland and Wolff, Ltd., at Govan, for the Royal Mail Lines, Ltd.; length between perpendiculars 415ft, breadth moulded 58ft 6in, depth moulded to shelter deck 38ft 4in; five cargo holds, fourteen derricks and one to lift 30 tons, electric winches; three 150kW diesel-driven generators; one Harland and Wolff single-acting, opposed-piston diesel engine, six cylinders, 620mm diameter by 1870mm combined stroke. Launch, May 29.

Catalogues and Brochures

BALFOUR BEATTY AND CO., Ltd., 66, Queen Street, London, E.C.4.—Illustrated brochure describing some of this company's activities.

HORWITCH SMITH AND CO., Ltd., Pensnett, Staffordshire.—Bulletin giving details of a standard range of rigid P.V.C. exhaust duct components.

EDWARDS HIGH VACUUM, Ltd., Manor Royal, Crawley, Sussex.—Illustrated booklet dealing with "Speedivac" rotary high vacuum pumps.

THE ALUMINIUM DEVELOPMENT ASSOCIATION, 33, Grosvenor Street, London, W.1.—List of films, film strips and wall charts available from A.D.A.

RANSOMES AND RAPIER, Ltd., Waterside Works, Ipswich.—Illustrated booklet describing the "Rapier 490" 2¼ cubic yard electric shovel or dragline.

TULLOCH CONSTRUCTION COMPANY, Ltd., Farringford House, Brighton Road, Sutton, Surrey.—Leaflet giving details of the "Tullcon" wire rope cutter.

THE BRITISH WEDGE WIRE COMPANY, Ltd., Academy Street, Warrington.—Leaflet describing the "Guidler" control mechanism for guiding conveyor belts.

NORTHEY ROTARY COMPRESSORS, Ltd., 200/202, Alder Road, Parkstone, Poole, Dorset.—Leaflets describing "Oil Free" compressors and vacuum pumps.

LIPTON L.P. CARBURETTER COMPANY, Ltd., Wooburn Green, Bucks.—Pamphlet illustrating and describing the "L.P. Gas" carburation system for fork lift trucks.

VISUAL PLANNING SYSTEMS, Ltd., Athlon Road, Manor Farm Estate, Alperton, Wembley, Middlesex.—Handbook; three dimensional factory planning equipment.

SERVICE ELECTRIC COMPANY, Ltd., Secomak Works, Honeypot Lane, Stanmore, Middlesex.—Leaflets describing "Secomak" electric syrens, whistles and sound signals.

KODAK, Ltd., Industrial Sales Division, Kodak House, Kingsway, London, W.C.2.—Catalogue giving technical details of the X-ray processing units manufactured by the company.

LONDON FAN AND MOTOR COMPANY, Ltd., 27, Brecknock Road, London, N.7.—Illustrated leaflet describing "Breeza" single-phase a.c. propeller fans, available in sizes 6in to 15in.

AUTOMATIC TELEPHONE AND ELECTRIC COMPANY, Ltd., Strowger Works, Liverpool, 7.—Leaflet describing the type "53" controller for vehicle and pedestrian-actuated road signal systems.

R. H. CORBETT AND CO., Ltd., Hydrum Works, Burgess Hill, Sussex.—Illustrated handbook for users of fork lift trucks, describing some of the attachments available and their particular uses.

SAMUEL OSBORN AND CO., Ltd., Clyde Steel Works, Sheffield, 3.—Folders giving details of "Mushet" drill packs, and pneumatic chisels and snaps, and a leaflet describing "Trushank" high-speed steel twist drills.

DESOUTTER BROTHERS, Ltd., The Hyde, Hendon, London, N.W.9.—Illustrated brochure describing multiple nutrunners, fitted with an automatic gear change motor producing high torque at a low air consumption.

THE ENGLISH ELECTRIC COMPANY, Ltd., Stafford.—Publication No. ES/126 issued by the control and electronics department, describing the "Deuce" universal digital computer and special purpose digital computers.

Q.V.F., Ltd., Duke Street, Fenton, Stoke-on-Trent, Staffs.—Catalogue entitled "Glass for Industry," describing and illustrating basic interchangeable chemical plant units. The catalogue has 130 pages and includes a detailed index.

BALDWIN INSTRUMENT COMPANY, Ltd., Brooklands Works, Dartford, Kent.—Fluid power catalogue, describing pneumatic and low pressure hydraulic equipment. Details are given of power cylinders, control valves, pilot valves and accessories.

ARCOLECTRIC SWITCHES, Ltd., Central Avenue, West Molesey, Surrey.—Illustrated catalogue describing the company's products. Three new groups have been included in this edition, micro-gap toggle switches, rotary switches and the sensitive snap action switch.

CAROBRONZE, Ltd., School Road, Belmont Road, London, W.4.—Brochure describing the properties of "Carobronze" cold drawn phosphor bronze tubes and rods for the production of bearing bushes, shaft sleeves, pump liners, twist nuts, guides and other anti-frictional components.

BAKELITE, Ltd., 12-18, Grosvenor Gardens, London, S.W.1.—Pamphlet describing copper-clad laminates for printed circuits, giving details of their construction and advantages over conventional wire connections. A list of "Bakelite" copper-clad laminates obtainable in standard grades and sizes is included.

T.I. NUCLEAR ENGINEERING, Ltd., The Adelphi, London, W.C.2.—Brochure giving details of the company's activities in the nuclear energy field, from the fabrication of the rare metals, including the manufacture of fuel element can tubes and sheaths to the supply of steel tubes and components for heat exchangers, stainless steel tubing, coils, pressure vessels, aluminium components, electrical switchgear, and rolling mills.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INTERPLANETARY SOCIETY

To-day and Sat., July 19 *to* 20.—JOINT MEETING WITH THE COLLEGE OF AERONAUTICS: College of Aeronautics, Cranfield, Symposium on "High Altitude and Satellite Rockets."

INSTITUTE OF THE MOTOR INDUSTRY

Sat. to Sat., Aug. 24 *to* 31.—St. Catharine's College, Cambridge, Eleventh Annual Summer School.

INSTITUTION OF MECHANICAL ENGINEERS

Wed., July 24.—N.W. BRANCH: Visit to Calder Hall Nuclear Power Station.

Sat., Aug. 31.—S. BRANCH: Whole-day visit to the pumping stations of the Mid-Wessex Water Company, Frimley, Surrey.

Sat., Sept. 14.—SOUTHERN BRANCH: Whole-day visit to the Greenham Common base of the United States Air Force, Newbury, Berks, 10 a.m.

PLASTICS INSTITUTE

To-day, July 19.—Conference Room, Gallery, National Hall, Olympia, London, W.14, Annual General Meeting, 12 noon.